NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

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EFFECT OF HULL LENGTH-BEAM RATIO ON THE HYDRODYNAMIC CHARACTERISTICS OF FLYING BOATS IN WAVES

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SUMMARY

An investigation was made of the take-off and landing behavior in waves of models of a hypothetical flying boat having hull length-beam ratios of 6 and 15. The flying boat had a design gross weight of 75,000 pounds, a wing loading of 41.1 pounds per square foot, and a power loading of 11.5 pounds per brake horsepower for take-off. The hull of high length-beam ratio was designed to meet advanced requirements for increased speed and increased range for flying-boat designs and has been shown to have low drag.

An increase in length-beam ratio from 6 to 15, reduced the maximum vertical accelerations during landing approximately 25 percent, increased the maximum angular accelerations during landing 15 to 30 percent, and reduced the motions in trim and rise as well as the maximum trim and rise. The reductions in trim and rise would make landings in waves less hazardous with the hull of high length-beam ratio than with the hull of low length-beam ratio.

In waves 2 feet high and 110 feet long, the range of speed and load over which spray entered the propellers during take-off was considerably greater with the length-beam ratio of 15 than with the length-beam ratio of 6. The spray entering the propellers of the hull with the high length-beam ratio, however, was acceptable. The hull with high length-beam ratio was less likely to reach a dangerous attitude during take-off than was the hull with low length-beam ratio; the take-off behavior with the high length-beam ratio was generally less violent.

INTRODUCTION

As part of a general investigation of the effect of hull length-beam ratio on the aerodynamic and hydrodynamic characteristics of flying boats, the landing and take-off behavior in oncoming waves of a hypothetical flying boat having hull length-beam ratios of 6 and 15 have been determined. These hulls are two of a related series with different length-beam ratios designed to have similar resistance and spray characteristics for the same gross weight and to be physically interchangeable on the same hypothetical seaplane design. All the hulls have the same length^2-beam product and, therefore, become longer and narrower as the length-beam ratio is increased.

The wind-tunnel investigation of the series (reference 1) has shown that the minimum aerodynamic drag of the hull with a length-beam ratio of 15 is 29 percent less than the drag of the hull with a length-beam ratio of 6. The tank investigations in smooth water of dynamic models with hull length-beam ratios of 6 and 15 (reference 2) have shown that the hydrodynamic qualities of the flying boat with the hull length-beam ratio of 15 are satisfactory and do not differ greatly from the qualities of the related flying boat with the more conventional hull length-beam ratio of 6.

The hypothetical seaplane design is a twin-engine propeller-driven flying boat having a design gross weight of 75,000 pounds, a wing loading of 41.1 pounds per square foot, and a power loading of 11.5 pounds per brake horsepower for take-off. Landings of powered dynamic models of this airplane with the two length-beam-ratio hulls were made in rough water corresponding to full-size waves of various sizes up to approximately 500 feet in length and 6 feet in height. Spray characteristics in a 2-foot wave and the behavior of the two hulls during taxi and take-off tests in 2-foot and 4-foot waves also were obtained.

SYMBOLS

C_{Δ_o}	gross load coefficient (Δ_o/wb^3)
b	maximum beam of hull, feet
g	acceleration due to gravity (32.2 ft/sec^2)
L	distance from forward perpendicular to sternpost, feet
n_v	vertical acceleration, g units
V_h	horizontal velocity (carriage speed), feet per second
V_v	vertical velocity (sinking speed), feet per second
w	specific weight of water (63.3 for these tests, usually taken as 64 for sea water), pounds per cubic foot
α	angular acceleration, radians per second per second
γ	flight-path angle, degrees

Δ_o gross load, pounds

τ trim (angle between forebody keel at step and horizontal), degrees

τ_L landing trim, degrees

DESCRIPTION OF MODELS AND APPARATUS

The form, size, and relative locations of the aerodynamic surfaces of the $\frac{1}{10}$-size powered dynamic models corresponded to those of a Navy twin-engine flying boat. The model having a hull length-beam ratio of 15 was designated Langley tank model 224 (fig. 1(a)). The model having a hull length-beam ratio of 6 was designated Langley tank model 213 (fig. 1(b)). The general arrangement of the flying boat is shown in figure 2. Pertinent characteristics and dimensions of the flying boats are given in table I. The length used for determining the length-beam ratio is the distance from the forward perpendicular to the sternpost.

The hulls have the same depth of step, position of the step relative to the mean aerodynamic chord, maximum depth of hull, ratio of forebody to afterbody length, and length^2-beam product. A detailed description and offsets of the hulls are given in reference 1. For convenience in making changes to the afterbodies, the fairing after the sternpost (reference 1) was omitted from the tank models and a slight modification was made to the sides of the afterbodies above the chine. These changes would have a negligible effect on the hydrodynamic characteristics.

The models were powered with three-blade metal propellers driven by two variable-frequency motors. Slats were attached to the leading edge of the wing in order to delay the stall to an angle of attack more nearly equal to that of the full-size airplane. The pitching moment of inertia of the ballasted models was 5.8 and 6.8 slug-feet square with length-beam ratios of 6 and 15, respectively.

The investigation was made in Langley tank no. 1, which is described in reference 3. The apparatus used for testing dynamic models is described in reference 4. The setup of model 224 on the towing carriage is shown in figure 3. The models were free to trim about the pivot, which was located at the center of gravity, and were free to move vertically but were restrained in roll and yaw. For the self-propelled tests in waves, the models had approximately 2 feet of fore-and-aft freedom with respect to the towing carriage in order to absorb the horizontal accelerations introduced by the impacts.

An accelerometer mounted on the towing staff of the model measured the vertical accelerations. Two accelerometers were used to measure the angular accelerations. These accelerometers, which were mounted 1 foot apart vertically, were located within the model in such a manner that their centers of gravity were in line with the center of gravity of the model. Slide-wire pickups were used to measure the trim, rise, and fore-and-aft position of the model. An electrically actuated trim brake, which was attached to the towing staff, fixed the trim of the model in the air and controlled the initial approach. The trim brake was automatically released when the hull contacted the water. In order to determine the part of the hull contacting the water, electrical contacts were located at the sternpost, at the step, and at a point approximately 40 percent of the forebody length aft of the forward perpendicular. Wave struts forward and aft of the model were used to record the wave profiles and to determine the length between wave crests.

Waves were generated by a wave maker which consists of a swinging plate hinged at the bottom and driven by a connecting rod at the top of the plate. These motions generate approximately trochoidal waves that travel from the north end of the tank through the test section and into an area where they are dissipated by a beach. The desired height and length of waves are obtained by a suitable combination of amplitude and frequency of the plate. Two landings usually are made during each test run of the wave maker. Between test runs, the wave maker is idle in order to permit dissipation of primary and reflected waves.

PROCEDURES

The investigation was made at the design gross load corresponding to 75,000 pounds, except for the spray investigation in which the gross loads corresponded to loads from 40,000 pounds to 75,000 pounds. The flaps were deflected 20° and the center of gravity was located at 32 percent mean aerodynamic chord.

Landing behavior.- The landing behavior was investigated by trimming the model in the air to the desired landing trim, at a speed slightly above flying speed, and then decelerating the towing carriage at a uniform rate of 2 feet per second per second, which allowed the model to glide onto the water and simulate an actual landing. Results of several tests in rough water have shown that, except at dangerously low trims, there was no appreciable effect of landing trim on either the variation of trim during the landing runout or the maximum accelerations. All landings were consequently made at approximately 8°. The behavior on landing was observed visually, and a time history of the landing behavior was continuously recorded throughout the landing run. The time history included recordings of trim, rise, fore-and-aft position, vertical accelerations, angular accelerations, wave profiles, and speed. The landings were made with power on and with the thrust adjusted so that the model upon initial contact with a wave was approximately a free body.

Spray characteristics.- The speeds at which spray entered the propellers were determined visually for gross loads from a lightly loaded to the normal gross-load condition.

Taxying and take-off behavior.- The taxying behavior in waves was investigated with full thrust up to hump speed at a forward rate of acceleration of 0.03g. The take-off behavior in waves was investigated with full thrust up to take-off speed at a forward rate of acceleration of approximately 0.1g. Complete time histories of the taxi and take-off runs were recorded.

RESULTS AND DISCUSSION

Landing Behavior

Photographs of typical records of landings in waves are shown as figure 4. Of particular interest are the records of vertical acceleration showing that the initial impact was less severe than several of the subsequent impacts. Angular accelerations above the mean are caused by a bow-down rotation resulting from a sternpost impact. These accelerations are considered as negative angular accelerations. The records indicated that the maximum vertical accelerations during a landing generally occurred when the forebody was approximately parallel to the forward slope of the wave. Furthermore, if the sternpost entered the water prior to or simultaneously with the step, the vertical acceleration was generally less than that of a forebody impact.

The results of all the landings in waves of hulls with length-beam ratios of 6 and 15 are presented in tables II and III, respectively, for use in further analysis. As may be seen in tables II and III, the sinking speeds for the initial landing approach ranged from 0.66 to 1.74 feet per second (125 to 330 ft/min, full size) and were small compared with the sinking speeds at the maximum vertical accelerations. The sinking speeds, preceding the maximum vertical accelerations, ranged from 0.92 to 7.44 feet per second (175 to 1410 ft/min, full size) with the low length-beam ratio and from 1.03 to 5.64 feet per second (195 to 1070 ft/min, full size) with the high length-beam ratio. In general, the sinking speeds at maximum vertical acceleration with the low length-beam ratio were greater than those with the high length-beam ratio.

Vertical accelerations.- The variation of vertical acceleration at initial impact with wave length is shown in figures 5 and 6 for length-beam ratios of 6 and 15, respectively. The vertical accelerations at initial impact were approximately 45 percent less at the long wave lengths than at the short wave lengths.

The variation of maximum vertical acceleration with wave length is shown in figures 7 and 8 for length-beam ratios of 6 and 15, respectively. At all wave heights a peak was reached in the vertical accelerations at the shorter wave lengths. At the longer wave lengths, the accelerations were approximately 50 percent less than the accelerations at the peak. An increase in wave height from 2 feet to 4 feet increased the peak accelerations approximately 45 percent. When wave height was increased from 4 feet to 6 feet, the peak accelerations remained approximately the same.

The position of landing on a wave for the initial impact as well as subsequent impacts during the landing runout was not under control of the operator, and this lack of control accounts for the scatter of the test data. The envelopes of the data indicate the maximum probable accelerations that would be obtained for the range of wave lengths investigated. The eight or ten landings made at most wave lengths were considered adequate to determine the maximum probable acceleration.

The effect of length-beam ratio on vertical accelerations during landings in waves is shown in figure 9. Length-beam ratio had a negligible effect on the accelerations at initial impact. Inasmuch as the hulls of low and high length-beam ratios had the same dead rise (20°) at the step, the wetted area of the two planing surfaces at initial impact was probably not very different, which would account for the accelerations being approximately the same. From observations of the landings, the chine immersion of the hull with high length-beam ratio appeared to be negligible on initial impact.

An increase in length-beam ratio from 6 to 15 reduced the peak maximum vertical accelerations approximately 25 percent. At impacts subsequent to the initial impact, the hull of high length-beam ratio had more tendency to cut through the waves than the hull of low length-beam ratio with consequent greater chine immersion. The reduction in vertical accelerations for the hull with the length-beam ratio of 15 would be expected on the basis of impact theory because of the larger chine immersion with the higher length-beam ratio. (See reference 5.)

The peak vertical acceleration for both the low and high length-beam ratios apparently occurred at the same wave length for each wave height. A comparison of the accelerations at initial impact and the maximum accelerations shows that the maximum acceleration always occurred at some impact subsequent to the initial and that the acceleration at initial impact was small compared with the maximum acceleration.

Angular accelerations.- The variation of angular acceleration at initial impact with wave length for the low and high length-beam ratios is shown in figures 10 and 11, respectively. The angular accelerations at initial impact were less at the longer wave lengths than at the shorter wave lengths. This reduction at longer wave lengths was approximately 60 percent in 4-foot waves and 50 percent in 6-foot waves. Some of the angular accelerations at initial impact were negative as a result of a sternpost impact, but the values were small compared with the positive accelerations.

The variation of maximum angular acceleration with wave length is shown in figures 12 and 13. A peak was reached in the positive angular accelerations (bow rotated upward) at the shorter wave lengths. At the longer wave lengths, the accelerations were reduced as much as 65 percent below the accelerations at the peak. An increase in wave height from 2 feet to 4 feet increased the peak accelerations approximately 50 percent; whereas an increase in wave height from 4 feet to 6 feet increased the peak accelerations less than 10 percent.

The negative angular accelerations occurred when a bow-down rotation was induced during landing on the sternpost. The negative accelerations were smaller at long wave lengths than at short wave lengths although the percentage reduction with increase in wave length was less than that of the positive accelerations.

The effect of length-beam ratio on angular accelerations during landings in waves is shown in figure 14. The length-beam ratio had a negligible effect on the accelerations at initial impact in 2-foot waves. Increasing the length-beam ratio from 6 to 15 increased the angular accelerations at initial impact approximately 35 percent in 4-foot waves and 60 percent in 6-foot waves.

An increase in length-beam ratio from 6 to 15 increased the peak maximum angular accelerations approximately 30 percent in 2-foot waves, 20 percent in 4-foot waves, and 15 percent in 6-foot waves. In 4-foot waves, the maximum negative angular accelerations at the peak were reduced 35 percent.

Motions in trim.- The maximum and minimum trims at the greatest cycle of oscillation that occurred during the landing run are plotted against wave length in figures 15 and 16 for length-beam ratios of 6 and 15, respectively. The variation of trim with wave length was small. The maximum cycle of oscillation in trim occurred at approximately the same wave length as that at which the peak maximum vertical acceleration occurred; a slight reduction in the trim cycle was obtained at wave lengths both shorter and longer than the wave length at which the maximum cycle was obtained.

The effect of length-beam ratio on the maximum and minimum trims during landings in waves is shown in figure 17. The maximum trims for both length-beam ratios exceeded the stall angle. The maximum trim with the low length-beam ratio was from 2° to 6° greater than that with the high length-beam ratio. The maximum change in trim with the high length-beam ratio was approximately 25 percent less than that with the low length-beam ratio. These reductions in the trim motions and in the maximum trims would make landings in waves less hazardous with the hull with high length-beam ratio.

Motions in rise.- The maximum and minimum rise at the greatest cycle of oscillation that occurred during the landing run are plotted against wave length in figures 18 and 19. In 4-foot waves, the greatest cycle occurred in waves approximately 240 feet in length. The maximum rise was reduced somewhat at wave lengths both shorter and longer than 240 feet.

The effect of length-beam ratio on the maximum and minimum rise during landings in waves is shown in figure 20. The maximum rise was reduced when the length-beam ratio was extended from 6 to 15. The maximum rise with the hull with low length-beam ratio was not determined in 4-foot waves for wave lengths between 160 and 250 feet and in 6-foot waves for lengths below 400 feet inasmuch as the rise would be in excess of that available in the tank. The minimum rise with both length-beam ratios in 4-foot and 6-foot waves was approximately the same.

Spray Characteristics

The range of speed over which spray entered the propellers in waves, 2 feet high and 110 feet long, is shown in figure 21. Distinguishing between light spray and heavy blister spray was not possible and, therefore, the comparison was made with the light-spray range of speed in smooth water (reference 2). The hull with the length-beam ratio of 6 tended to ride over the tops of the waves and the range of speed and load over which any spray entered the propellers was reduced for this particular wave. The hull with the length-beam ratio of 15 tended to cut through the tops of the waves, however, and the range of speed and load was increased when compared with the range for smooth water. In waves 2 feet high and 110 feet long, the range of speed and load over which spray entered the propellers was considerably greater with the high length-beam ratio than with the low length-beam ratio. The spray entering the propellers with the high length-beam ratio was acceptable, however, based on the observations of the spray characteristics of a number of models of successful conventional flying boats.

Taxying and Take-Off Behavior

The results of the investigation of the taxying and take-off behavior of the hulls with low and high length-beam ratios in rough water are qualitative, but several points are of interest. Although the trim cycles were large in 4-foot waves, the bows did not dig in. Observations indicated, however, that a decrease in length of either forebody would not be advisable under these conditions.

Tracings of typical records made during take-offs in waves for both hulls are shown in figures 22 and 23. Both hulls demonstrated a tendency to follow the waves in the trim and rise motions at the lower speeds. The phase relationships of trim and rise are of interest in that the rise reached a maximum shortly before the trim reached a minimum.

The trim and rise motions with the length-beam ratio of 6 were small in 2-foot waves until take-off speed was approached. At a speed corresponding to 50 miles per hour, the model reached a stalled attitude and since flying speed had not been obtained, the model fell back into the water. Upon contact with a wave, the model again bounced clear of the water and trimmed to a stalled attitude.

In 4-foot waves, the motions in trim and rise with the length-beam ratio of 6 were large and the stall angle was exceeded near hump speed. In waves 4 feet high and 200 feet long, the take-off run was discontinued at a speed corresponding to 55 miles per hour in order to avoid possible damage. In waves 4 feet high and 150 feet long, the model came clear of the water at a speed corresponding to 55 miles per hour, reached a stalled attitude, and fell back into the water with an impact acceleration of 2.5g. Upon contact with a wave, the model again bounced clear of the water and trimmed to a stalled attitude. Flying speed was obtained before the model again entered the water. At high speeds, the behavior in 2-foot and 4-foot waves did not differ greatly.

In 2-foot waves (fig.23) the oscillations in rise with the length-beam ratio of 15 were very small. The oscillations in trim were not great and the trim did not exceed the stall angle during the take-off run.

In 4-foot waves, the oscillations in trim and rise at low speeds were large but did not appear to be dangerous. At higher speeds the oscillations became small as the hull planed over the wave crests and relatively stable take-offs were made. A comparison of the take-offs for the hull with high length-beam ratio shows the marked difference in the motions in 2-foot and in 4-foot waves.

The take-off investigation in rough water indicated that the hull with high length-beam ratio was less likely to reach a dangerous attitude than was the hull with low length-beam ratio; the take-off behavior with the hull of high length-beam ratio was generally less violent.

CONCLUSIONS

The results of the investigation of the behavior in waves of a hypothetical flying boat having hull length-beam ratios of 6 and 15 at a gross load corresponding to 75,000 pounds led to the following conclusions:

1. An increase in length-beam ratio from 6 to 15 reduced the maximum vertical accelerations during landing approximately 25 percent.

2. An increase in length-beam ratio from 6 to 15 increased the maximum angular accelerations during landing 15 to 30 percent.

3. An increase in length-beam ratio from 6 to 15 reduced the motions in trim and rise as well as the maximum trim and rise. These reductions would make landings in waves less hazardous with the hull of high length-beam ratio than with the hull of low length-beam ratio.

4. In waves 2 feet high and 110 feet long, the range of speed and load over which spray entered the propellers during take-off was considerably greater with the length-beam ratio of 15 than with the length-beam ratio of 6. The spray entering the propellers for the hull with high length-beam ratio, however, was acceptable.

5. The hull with high length-beam ratio was less likely to reach a dangerous attitude during take-off than was the hull with low length-beam ratio; the take-off behavior for the hull with high length-beam ratio was generally less violent.

Langley Aeronautical Laboratory
National Advisory Committee for Aeronautics
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TABLE I

PERTINENT CHARACTERISTICS AND DIMENSIONS OF FLYING BOATS

HAVING HULL LENGTH-BEAM RATIOS OF 6 AND 15

	$\frac{L}{b} = 6$	$\frac{L}{b} = 15$
General		
Design gross load, lb	75,000	75,000
Gross load coefficient, C_{Δ_0}	0.94	5.88
Wing area, sq ft	1826	1826
Take-off horsepower	6500	6500
Wing loading, lb/sq ft	41.1	41.1
Power loading, lb/hp	11.5	11.5
Hull		
Maximum beam, ft	10.76	5.84
Length:		
Forebody, bow to step, ft	37.1	50.4
Forebody length-beam ratio	3.5	8.6
Afterbody, step to sternpost, ft	27.4	37.2
Afterbody length-beam ratio	2.5	6.4
Tail extension, sternpost to aft perpendicular, ft	27.3	17.5
Over-all, bow to aft perpendicular, ft	91.8	105.1
Step:		
Type	Transverse	Transverse
Depth at keel, in.	11.6	11.6
Depth at keel, percent beam	9.0	16.5
Angle of forebody keel to base line, deg	0	0
Angle of afterbody keel to base line, deg	5.4	5.4
Angle of sternpost to base line, deg	7.4	6.9
Angle of dead rise of forebody:		
Excluding chine flare, deg	20	20
Including chine flare, deg	16.5	16.5
Angle of dead rise of afterbody, deg	20	20
Wing		
Span, ft	139.7	139.7
Root chord, ft	16.0	16.0
Mean aerodynamic chord (M.A.C.):		
Length, projected, ft	13.7	13.7
Leading edge aft of bow, ft	30.4	43.7
Leading edge forward of step, ft	6.7	6.7
Leading edge above base line, ft	15.1	15.1
Angle of incidence, deg	4	4

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TABLE I — Concluded

PERTINENT CHARACTERISTICS AND DIMENSIONS OF FLYING BOATS — Concluded

	$\frac{L}{b} = 6$	$\frac{L}{b} = 15$
Horizontal tail surfaces		
Area, sq ft	333	333
Span, ft	43.0	43.0
Angle of stabilizer to wing chord, deg	−4	−4
Elevator root chord, ft	3.20	3.20
Elevator semispan, ft	16.7	16.7
Length from 25 percent M.A.C. of wing to hinge line of elevators, ft	49.5	49.5
Height above base line, ft	19.0	19.0
Propellers		
Number of propellers	2	2
Number of blades	3	3
Diameter, ft	16.5	16.5
Angle of thrust line to base line, deg	2	2
Clearance above keel, ft	8.3	8.3

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TABLE II

DATA OBTAINED DURING LANDINGS IN WAVES
LENGTH-BEAM RATIO, 6

[All values are model size]

Landing	Wave height (ft)	Wave length (ft)	Initial impact						Maximum acceleration						
			τ_L (deg)	V_v (fps)	V_h (fps)	γ (deg)	n_v (g)	α $\left(\frac{\text{radians}}{\text{sec}^2}\right)$	Impact	τ (deg)	V_v (fps)	V_h (fps)	γ (deg)	n_v (g)	α $\left(\frac{\text{radians}}{\text{sec}^2}\right)$
1	0.2	10.4	10.0	1.26	33.0	2.2	1.5	10	5	9.5	2.87	25.8	6.4	3.8	57
2	.2	11.0	9.4	1.13	33.0	2.0	1.6	4	6	7.4	3.53	26.6	7.6	5.6	66
3	.2	11.0	10.0	1.16	32.9	2.0	1.6	4	7	8.3	3.08	25.7	6.8	3.3	43
									[a]10	9.0	2.47	20.8	6.8	3.1	50
4	.2	11.0	9.5	1.12	33.5	1.9	3.1	33	6	9.6	3.81	22.0	9.8	4.3	25
									[a]3	10.9	3.64	27.9	7.4	3.3	50
5	.2	11.0	8.0	1.10	36.9	1.7	1.0	2	6	9.9	2.10	29.6	4.0	4.8	40
									[a]8	6.2	2.83	26.2	6.2	4.1	48
6	.2	10.6	8.0	.94	36.8	1.4	2.0	13	5	10.0	3.20	28.0	6.5	5.0	29
									[a]7	5.0	3.40	25.3	7.6	3.8	54
7	.2	11.2	8.0	1.03	38.0	1.6	2.0	14	3	4.9	2.70	32.1	4.8	4.9	75
8	.2	10.5	8.0	1.55	36.0	2.5	2.0	29	5	8.7	2.60	29.6	5.0	4.6	31
									[a]7	5.9	2.51	27.7	5.2	3.7	42
9	.2	11.3	8.1	1.04	37.4	1.6	.8	0	5	8.1	1.18	29.6	2.1	4.0	50
10	.2	12.9	7.5	1.15	37.3	1.8	2.0	20	5	8.7	4.46	27.8	9.1	6.0	40
									[a]4	6.0	3.81	29.6	7.4	3.2	52
11	.2	12.4	7.5	.97	38.3	1.4	1.8	18	6	6.5	4.21	28.2	8.5	3.3	53
12	.2	12.4	7.5	1.10	38.1	1.6	1.4	10	7	7.8	4.11	26.2	8.9	5.2	23
									[a]5	7.5	4.90	29.7	9.3	4.4	53
13	.2	12.4	7.6	1.02	37.9	1.5	1.8	10	4	5.0	2.53	32.6	4.4	3.8	46
14	.2	12.7	7.5	1.03	37.8	1.6	2.0	20	3	6.3	2.96	33.3	5.1	5.3	48
15	.2	14.3	8.0	1.08	36.2	1.7	2.0	10	6	9.5	4.06	25.3	9.0	6.7	36
									[a]3	9.3	3.33	31.9	6.0	4.1	43
16	.2	14.3	8.0	1.05	36.5	1.6	1.4	10	9	11.4	3.07	25.0	7.0	7.2	56
17	.2	14.3	8.2	.97	36.8	1.5	2.9	28	7	10.9	4.55	26.2	9.8	5.9	29
									[a]5	11.4	1.04	30.6	2.0	2.9	38
18	.2	13.8	8.7	1.01	36.2	1.6	2.5	23	6	10.1	4.86	25.8	10.7	5.2	22
									[a]5	11.1	3.73	28.0	7.6	4.7	60
19	.2	14.3	8.8	.97	36.3	1.5	2.6	20	6	9.2	4.08	26.1	8.9	6.3	25
									[a]5	11.5	3.72	28.3	7.5	3.9	58
20	.2	14.3	7.6	.81	38.0	1.2	2.2	13	8	8.4	3.33	28.2	6.7	5.2	26
									[a]11	7.2	3.36	25.2	7.6	3.3	46
21	.2	14.8	7.8	.74	37.6	1.1	2.6	16	6	8.3	4.99	24.6	11.5	5.7	41
									[a]4	10.7	4.44	29.0	8.7	3.5	51
22	.2	14.3	7.6	1.03	37.8	1.6	1.3	5	6	9.5	5.40	28.8	10.6	8.3	52
23	.2	16.8	8.2	1.07	36.3	1.7	2.3	9	3	9.8	3.75	30.5	7.0	4.1	13
									[a]2	4.7	2.10	34.0	3.6	3.3	38
24	.2	17.8	8.0	.99	37.0	1.5	.4	-6	4	9.4	3.81	26.8	8.1	5.2	21
									[a]3	8.5	3.94	29.0	7.7	3.6	37
25	.2	17.8	8.0	1.03	36.4	1.6	.5	-8	4	9.9	4.43	26.5	9.5	4.5	28
									[a]3	7.3	3.98	28.8	7.9	3.2	33
26	.2	17.3	8.2	1.04	36.5	1.6	1.0	4	6	10.2	3.91	27.5	8.1	4.2	20
									[a]5	3.8	2.58	29.6	5.0	2.7	36
27	.2	17.5	8.2	1.09	36.1	1.8	2.3	20	5	10.2	4.70	26.8	9.9	6.9	32
28	.2	19.0	8.1	1.15	36.2	1.8	1.5	0	4	8.2	3.12	29.5	6.0	4.5	25
									[a]5	7.9	3.26	27.8	6.7	3.2	33
29	.2	19.0	8.1	1.07	36.1	1.7	.8	-9	4	8.1	4.41	27.0	9.3	4.4	44
30	.2	20.2	8.2	1.17	36.2	1.8	1.1	0	7	8.4	3.87	27.9	7.9	5.4	25
31	.2	19.8	8.1	1.02	36.9	1.6	.7	0	4	8.8	4.23	27.0	8.9	6.0	25
									[a]3	3.5	2.42	29.5	4.7	2.5	31
32	.4	12.1	8.8	1.12	35.3	1.8	2.5	20	4	11.9	2.20	28.0	4.5	7.5	104
33	.4	12.3	8.5	1.15	35.9	1.8	3.7	40	3	9.5	2.73	31.0	5.0	8.4	95
34	.4	13.0	8.9	1.05	35.5	1.7	3.0	32	9	7.1	3.62	24.2	8.5	7.6	106
35	.4	13.0	9.2	1.13	35.0	1.8	4.6	40	7	7.4	4.07	23.3	9.9	7.8	95
36	.4	12.7	8.0	1.03	36.1	1.6	2.9	10	5	10.3	5.02	26.6	10.7	10.5	43
37	.4	15.8	8.5	1.50	35.0	2.5	2.9	15	7	8.5	5.15	23.2	12.5	9.5	81
38	.4	15.6	8.5	1.07	35.0	2.0	2.4	12	5	10.5	5.91	24.2	13.7	10.8	40
									[a]6	4.5	3.81	26.1	8.3	5.1	63
39	.4	15.1	8.5	1.58	35.5	2.5	2.3	8	5	10.9	4.78	28.2	9.6	8.2	30
40	.4	16.0	8.6	1.25	35.3	2.0	.6	-10	3	10.0	5.81	28.7	11.4	9.6	56
41	.4	15.7	8.0	1.38	37.0	2.2	4.4	36	4	10.4	5.28	28.0	10.7	10.5	37
									[a]2	5.2	3.25	33.0	5.6	6.3	80
42	.4	15.7	8.0	1.04	37.2	1.6	3.0	30	5	9.1	4.55	25.5	10.1	10.7	76
									[a]4	9.5	6.08	27.7	12.4	9.8	80
43	.4	15.4	8.0	.98	37.8	1.5	3.0	18	4	9.5	6.03	28.0	12.1	7.2	93
44	.4	15.4	8.0	1.06	37.3	1.6	3.2	24	4	7.0	6.20	27.2	12.8	7.4	98
45	.4	16.4	7.5	.90	38.0	1.4	3.0	32	9	9.3	---	20.3	---	6.5	26
									[a]5	4.4	---	28.0	---	4.2	73
46	.4	16.6	7.6	.98	38.0	1.5	3.4	39	5	3.7	---	27.8	---	6.2	90
47	.4	16.8	7.4	.92	37.2	1.4	3.0	24	6	8.9	5.92	25.0	13.3	9.9	39
									[a]2	3.3	3.41	34.0	5.9	3.3	61
48	.4	17.3	7.5	1.09	37.0	1.7	1.2	0	7	9.2	6.23	24.9	14.0	8.8	43
									[a]6	12.0	5.48	27.4	11.3	5.3	77
49	.4	18.0	7.5	1.06	37.0	1.6	2.0	9	6	9.4	---	25.4	---	9.1	38
									[a]4	5.5	.92	30.0	2.1	3.2	52

[a]Impact for maximum angular acceleration.

TABLE II - Continued

DATA OBTAINED DURING LANDINGS IN WAVES - Continued

Landing	Wave height (ft)	Wave length (ft)	Initial impact τ_L (deg)	V_v (fps)	V_h (fps)	γ (deg)	n_v (g)	α $\left(\frac{\text{radians}}{\text{sec}^2}\right)$	Maximum acceleration Impact	τ (deg)	V_v (fps)	V_h (fps)	γ (deg)	n_v (g)	α $\left(\frac{\text{radians}}{\text{sec}^2}\right)$
50	0.4	17.3	7.5	1.09	37.0	1.7	2.0	9	6	9.5	5.92	28.2	11.8	8.9	45
									[a]8	5.7	5.00	25.1	11.3	5.2	72
51	.4	17.2	7.4	1.03	36.7	1.6	2.4	13	4	8.1	5.59	29.9	10.6	8.5	35
									[a]8	6.9	5.76	23.4	13.6	6.3	57
52	.4	16.7	7.6	1.09	37.0	1.7	2.0	0	6	9.9	7.16	27.8	14.4	11.5	57
									[a]5	4.2	4.44	30.0	8.4	5.5	79
53	.4	16.9	7.6	1.08	37.3	1.7	3.2	30	5	8.9	6.79	28.2	13.5	11.4	65
									[a]8	9.8	6.74	23.0	16.3	7.1	72
54	.4	16.7	7.6	1.26	37.2	1.9	2.9	14	5	9.4	5.90	28.5	11.7	9.0	45
									[a]6	5.4	5.30	26.8	11.2	7.0	85
55	.4	16.2	7.6	1.23	37.5	1.9	.6	-9	6	9.0	5.64	25.8	12.3	9.1	43
									[a]2	1.4	4.42	34.2	7.4	4.7	90
56	.4	16.4	7.6	1.04	37.8	1.6	3.6	42	3	9.1	4.67	31.6	8.4	9.2	59
57	.4	16.3	8.4	1.09	36.5	1.7	3.7	45	5	8.1	4.92	25.0	11.1	6.5	66
									[a]2	10.0	3.24	32.9	5.6	3.8	77
58	.4	17.0	8.4	1.13	37.4	1.8	3.2	24	3	9.2	5.94	31.4	10.7	8.9	46
									[a]2	4.0	3.85	33.9	6.5	5.5	98
59	.4	17.0	8.4	.98	37.8	1.6	3.4	30	5	10.8	5.72	26.3	12.3	9.8	38
									[a]3	8.1	4.20	31.7	7.6	6.7	74
60	.4	16.9	8.4	1.72	37.9	2.6	6.3	71	5	9.5	5.92	25.8	12.9	11.6	116
61	.4	17.0	8.0	1.05	37.7	1.6	3.5	24	3	9.1	6.02	31.4	10.8	9.0	60
									[a]2	4.7	4.39	33.8	7.4	6.3	81
62	.4	16.6	8.0	.99	36.9	1.5	4.3	33	5	9.3	4.36	25.3	9.8	9.5	71
									[a]2	6.5	2.42	33.0	4.2	7.3	81
63	.4	19.6	9.0	1.21	34.5	2.0	2.5	9	5	11.0	4.62	26.5	9.9	8.8	42
									[a]3	8.9	5.06	30.0	9.6	8.6	50
64	.4	20.1	9.6	1.53	33.2	2.6	1.7	4	5	11.5	5.61	25.0	12.7	9.8	49
									[a]4	12.6	4.00	27.8	8.2	5.1	66
65	.4	20.0	8.0	1.02	36.6	1.6	2.8	15	5	10.8	5.97	26.3	12.8	10.8	60
66	.4	20.1	7.7	1.19	37.0	1.8	0	-5	5	9.2	6.28	28.3	12.5	9.2	44
									[a]7	11.2	5.34	24.2	12.4	4.1	72
67	.4	19.3	9.0	1.74	35.5	2.8	3.7	11	2	8.1	2.47	33.0	4.3	6.9	53
68	.4	20.3	9.0	1.72	35.7	2.8	5.2	40	4	9.5	4.08	28.2	8.2	9.3	44
									[a]7	10.4	4.67	24.1	11.0	3.5	48
69	.4	20.2	7.6	.96	37.5	0	3.0	27	5	9.3	7.09	27.0	14.7	11.5	50
									[a]2	7.5	4.04	33.9	6.8	8.9	86
70	.4	19.8	7.7	1.10	37.5	1.7	.8	7	5	10.0	6.70	26.6	14.1	11.5	57
									[a]2	6.2	4.67	33.6	7.9	6.6	67
71	.4	20.2	7.6	1.06	37.3	1.6	.5	12	3	6.9	5.20	32.0	9.2	9.9	87
72	.4	19.7	7.6	1.17	37.4	1.8	3.0	19	4	7.1	6.59	30.6	12.2	8.2	70
73	.4	23.7	7.7	1.41	36.5	2.2	2.0	0	4	9.6	5.34	29.6	11.2	10.2	37
									[a]2	4.4	2.09	34.6	3.5	3.6	50
74	.4	22.9	8.0	1.50	35.8	2.4	3.0	5	7	5.7	4.85	23.9	11.5	5.7	55
75	.4	22.0	7.9	1.38	36.2	2.2	.8	5	3	8.8	5.76	30.3	10.7	8.2	36
76	.4	22.8	7.5	---	37.7	---	1.6	0	8	5.6	---	23.1	---	6.0	65
77	.4	23.1	7.4	1.07	37.0	1.7	0	-8	4	9.7	4.90	27.5	10.1	6.8	32
									[a]2	8.9	4.10	33.4	7.0	5.4	36
78	.4	23.3	7.7	.83	36.3	1.3	2.2	10	5	10.3	5.24	28.0	10.6	7.2	40
79	.4	22.9	7.8	1.58	35.5	2.5	3.4	18	4	8.0	5.84	26.4	12.5	7.6	44
									[a]6	5.4	4.29	22.5	10.8	6.2	65
80	.4	22.4	8.0	1.09	36.1	1.7	3.2	22	4	9.4	6.44	28.1	12.9	9.9	40
81	.4	22.3	8.0	1.08	35.9	1.7	3.6	33	3	9.2	5.07	30.0	9.6	8.4	40
									[a]5	9.2	5.38	25.2	12.0	7.0	70
82	.4	33.5	7.9	1.12	36.2	1.8	1.2	9	6	6.3	5.06	25.0	11.4	6.3	46
83	.4	32.5	8.2	1.49	36.0	2.4	4.1	20	1	---	---	---	---	4.1	20
									[a]7	3.5	4.89	24.1	11.5	3.9	38
84	.4	33.0	7.9	1.40	36.9	2.2	2.6	14	2	7.5	2.79	33.9	4.7	4.2	27
									[a]3	7.6	3.21	31.4	5.9	3.2	31
85	.4	33.6	7.9	1.45	35.9	2.3	.6	-10	7	7.8	5.02	24.2	11.7	7.1	34
									[a]6	6.1	3.53	26.1	7.6	4.4	37
86	.4	33.0	8.2	.88	35.4	1.4	.5	-5	3	9.2	3.62	31.5	6.6	6.2	29
									[a]5	6.2	4.21	26.7	9.0	5.4	44
87	.4	33.4	8.2	1.40	35.0	2.3	1.3	-12	7	5.6	5.14	23.5	12.3	6.7	36
88	.4	33.4	8.3	1.10	35.1	1.8	.8	-11	4	9.4	4.60	28.6	9.2	5.7	43
89	.6	21.7	8.2	1.01	36.0	1.6	2.5	12	5	9.6	6.14	25.9	13.3	11.2	73
90	.6	22.6	8.3	.94	36.1	1.5	.8	-5	4	11.2	5.84	26.3	12.5	11.5	35
									[a]2	8.6	4.10	31.3	7.5	9.0	80
91	.6	22.5	8.2	.90	36.0	1.4	3.7	40	3	8.0	4.89	29.4	9.5	8.4	60
									[a]2	7.5	4.00	32.4	7.0	8.2	75
92	.6	21.5	8.2	1.11	36.0	1.8	4.3	32	3	8.7	5.44	29.3	10.5	8.0	44
									[a]2	3.9	2.64	32.0	4.7	4.8	70
93	.6	21.5	8.2	1.12	35.4	1.8	2.6	12	6	8.0	5.91	24.6	13.5	6.3	40
									[a]5	8.7	5.16	26.9	10.9	3.5	47
94	.6	22.7	8.4	.93	34.8	1.5	3.3	27	4	9.9	5.12	26.5	10.9	9.5	31
									[a]3	6.2	6.02	29.0	11.7	9.0	81

[a]Impact for maximum angular acceleration.

NACA

TABLE II - Concluded

DATA OBTAINED DURING LANDINGS IN WAVES - Concluded

Landing	Wave height (ft)	Wave length (ft)	Initial impact τ_L (deg)	V_v (fps)	V_h (fps)	γ (deg)	n_v (g)	α $\left(\frac{\text{radians}}{\text{sec}^2}\right)$	Maximum acceleration Impact	τ (deg)	V_v (fps)	V_h (fps)	γ (deg)	n_v (g)	α $\left(\frac{\text{radians}}{\text{sec}^2}\right)$
95	0.6	22.9	8.4	0.98	35.0	1.6	1.8	3	6	7.1	5.70	24.7	13.0	7.2	57
									[a]3	7.8	4.42	30.3	8.3	6.2	60
96	.6	24.2	7.9	.85	38.0	1.3	1.0	6	4	10.1	6.59	28.0	13.2	11.4	56
									[a]9	7.4	6.07	21.0	16.1	8.7	75
97	.6	24.4	8.0	.98	37.3	1.5	2.5	8	3	6.7	6.09	32.0	10.8	12.0	108
98	.6	24.0	8.2	.93	37.9	1.4	.5	-5	4	7.7	5.71	29.1	11.1	12.4	127
99	.6	26.1	8.1	.75	38.0	1.1	1.0	0	6	8.5	5.70	29.0	11.1	9.5	71
100	.6	26.0	8.1	.87	38.2	1.3	.8	-3	5	9.5	5.26	28.0	10.6	8.4	37
									[a]3	7.7	3.05	34.0	5.1	6.1	50
101	.6	24.1	8.1	.98	37.7	1.5	2.5	12	4	8.0	6.78	28.8	13.2	10.5	62
102	.6	24.4	8.2	.91	37.6	1.4	2.8	13	3	7.5	5.66	31.2	10.3	11.1	121
103	.6	23.3	8.1	.66	37.9	1.0	1.8	0	5	9.4	7.28	28.0	14.6	11.3	60
104	.6	25.0	8.1	.99	38.0	1.5	3.0	15	4	8.4	5.76	28.6	11.4	11.3	96
105	.6	23.8	8.1	1.00	38.3	1.5	1.5	0	6	9.0	5.38	28.2	10.8	9.2	58
									[a]10	6.1	4.54	21.4	12.0	7.3	83
106	.6	23.8	8.2	.84	38.5	1.2	.4	-7	3	5.2	5.76	33.0	9.9	8.5	90
107	.6	24.2	8.5	.97	38.9	1.4	.4	-6	6	7.6	6.94	26.8	14.5	11.3	103
108	.6	25.2	8.1	.97	36.4	1.5	.9	4	4	6.8	7.35	26.1	15.7	4.5	70
109	.6	25.1	---	1.05	36.9	1.4	1.2	0	4	---	7.24	26.0	15.6	11.0	62
									[a]7	---	4.78	21.4	12.6	6.2	85
110	.6	25.2	---	.98	36.7	1.5	.8	-8	4	---	8.01	26.5	16.8	11.0	100
111	.6	24.8	---	.97	36.5	1.5	0	0	4	---	7.44	27.4	15.2	11.2	118
112	.6	24.3	---	1.02	36.8	1.6	2.2	7	5	---	7.37	26.7	15.4	10.3	68
									[a]7	---	5.46	22.0	13.9	7.6	87
113	.6	25.3	7.9	.91	36.8	1.4	2.7	19	4	7.6	7.07	28.7	13.8	10.8	64
									[a]8	---	5.19	25.5	11.7	8.9	89
114	.6	23.6	7.9	1.15	37.0	1.8	.9	0	4	7.4	7.29	28.3	14.4	10.9	66
115	.6	29.1	8.2	.82	36.8	1.3	3.1	32	2	7.3	3.85	33.4	6.6	6.5	50
									[a]5	6.4	4.64	25.3	10.4	6.3	57
116	.6	30.6	8.2	.94	36.3	1.5	2.1	6	4	7.1	5.22	28.9	10.3	7.4	45
									[a]6	5.4	4.76	24.5	11.0	6.0	71
117	.6	28.1	8.3	.84	36.2	1.3	1.9	5	4	7.6	5.25	29.1	10.2	6.8	37
									[a]2	3.6	2.38	34.5	3.9	3.2	45
118	.6	29.6	8.2	.93	36.8	1.4	1.9	-4	4	8.8	4.29	29.5	8.3	6.9	40
									[a]6	4.0	5.01	25.4	11.1	6.4	85
119	.6	28.1	8.5	.94	36.5	1.5	1.2	0	4	7.6	5.64	29.2	10.9	9.5	68
120	.6	29.1	8.4	.82	37.0	1.3	0	-8	4	8.1	5.99	28.4	11.9	9.6	60
121	.6	29.6	8.4	1.03	36.7	1.6	3.0	16	5	6.8	4.63	26.0	10.1	7.0	63
122	.6	31.0	8.0	1.04	37.0	1.6	2.4	4	5	6.1	5.06	26.0	11.0	7.4	64
123	.6	31.5	8.0	1.20	36.6	1.9	2.9	10	6	5.9	4.93	24.9	11.2	6.8	33
124	.6	31.7	8.1	1.11	36.6	1.7	.4	0	7	5.7	5.24	22.8	13.0	7.0	64
125	.6	31.2	8.0	1.06	36.8	1.6	2.6	8	3	8.8	5.52	30.0	10.4	7.1	38
									[a]6	6.0	5.08	25.0	11.7	6.5	59
126	.6	32.8	8.0	1.17	36.2	1.8	2.3	7	5	8.0	5.36	25.9	11.7	7.3	30
									[a]4	7.7	6.20	28.0	12.5	4.0	47
127	.6	32.0	8.0	1.07	37.2	1.6	2.1	16	2	7.1	4.46	33.9	7.5	6.9	65
128	.6	38.3	8.5	.82	38.3	1.2	1.4	0	8	4.2	5.74	25.8	12.5	5.6	57
129	.6	40.2	8.4	.82	37.9	1.2	2.1	10	3	3.3	3.74	31.6	6.8	4.3	40
130	.6	43.2	8.4	.85	38.3	1.3	1.7	2	7	6.6	4.73	25.0	10.7	6.1	40
									[a]6	6.0	4.73	26.7	10.1	5.8	43
131	.6	39.4	8.5	.88	38.5	1.3	2.2	6	3	8.8	4.06	32.6	7.1	6.0	30
									[a]6	2.7	5.64	25.9	12.3	4.6	50
132	.6	41.2	8.5	.84	39.0	1.2	2.3	25	5	7.8	4.31	27.6	8.9	5.9	29
									[a]4	6.9	4.56	29.4	8.8	5.8	42
133	.6	39.0	8.4	.93	35.3	1.5	.7	-7	6	5.0	5.42	23.1	13.2	5.5	39
134	.6	41.5	8.4	.97	34.8	1.6	2.6	7	2	8.2	2.95	31.7	5.3	4.7	21
135	.6	41.4	8.4	.99	35.2	1.6	1.1	-5	6	5.9	5.36	24.8	12.2	7.0	51
136	.6	46.0	8.3	1.31	35.9	2.1	2.6	6	1	8.3	1.31	35.9	2.1	2.6	6
									[a]3	4.1	3.17	31.0	5.8	2.3	19
137	.6	45.1	8.3	.98	36.1	1.6	2.2	11	2	7.1	3.86	32.8	6.7	4.0	27
138	.6	44.9	8.4	.98	36.5	1.5	2.0	5	5	6.3	4.84	27.3	10.1	5.1	30
									[a]4	8.7	4.48	29.0	8.8	4.4	38
139	.6	45.5	8.4	.90	36.8	1.4	2.5	7	6	3.5	5.68	26.2	12.2	4.8	43
140	.6	45.2	8.4	.80	37.2	1.2	.6	-5	3	9.8	3.68	30.3	6.9	3.3	23
									[a]2	7.2	3.86	32.8	6.7	3.0	29
141	.6	46.8	8.2	1.20	35.0	2.0	2.1	10	4	8.4	3.75	27.5	7.8	5.1	26
142	.6	46.8	8.3	1.00	36.0	1.8	.5	-7	4	4.7	4.62	27.5	9.5	3.6	20
143	.6	47.5	8.3	1.16	35.2	1.9	1.8	7	5	4.5	5.45	25.8	11.9	4.5	33
144	.6	42.9	8.3	1.04	36.0	1.6	.9	-9	4	7.3	---	26.8	---	6.6	34
									[a]3	4.8	4.21	29.2	8.2	4.4	40
145	.6	47.2	8.2	.94	36.3	1.5	1.0	-8	5	5.3	5.28	27.7	10.8	2.9	25
									[a]4	2.6	4.20	29.7	8.0	2.6	30
146	.6	48.1	8.2	.89	36.5	1.4	1.6	16	5	7.6	4.76	27.0	10.0	6.9	35
147	.5	47.2	8.3	.87	36.0	1.4	1.4	6	5	8.0	5.10	26.4	10.9	7.5	32
									[a]4	5.5	4.00	28.8	7.9	4.8	46

[a]Impact for maximum angular acceleration.

TABLE III

DATA OBTAINED DURING LANDINGS IN WAVES
LENGTH-BEAM RATIO, 15

[All values are model size]

Landing	Wave height (ft)	Wave length (ft)	Initial impact						Maximum acceleration						
			τ_L (deg)	V_v (fps)	V_h (fps)	γ (deg)	n_v (g)	α $\left(\frac{\text{radians}}{\text{sec}^2}\right)$	Impact	τ (deg)	V_v (fps)	V_h (fps)	γ (deg)	n_v (g)	α $\left(\frac{\text{radians}}{\text{sec}^2}\right)$
1	0.2	10.9	6.7	1.46	36.8	2.3	1.6	12	7	4.9	2.36	29.1	4.6	3.3	39
									a8	4.2	2.14	26.3	4.7	2.8	53
2	.2	10.9	6.8	1.62	36.7	2.5	2.2	15	3	3.6	2.43	33.2	4.2	4.2	52
3	.2	11.2	6.7	1.67	36.7	2.6	1.5	14	7	5.0	2.82	27.0	6.0	4.7	52
4	.2	11.1	6.8	1.62	36.7	2.5	2.1	12	7	5.2	2.52	27.3	5.3	3.8	45
									a8	4.4	2.32	25.7	5.2	2.4	49
5	.2	11.1	7.0	1.26	37.0	2.0	2.0	7	7	4.7	2.86	27.1	6.0	4.8	55
									a4	3.4	2.11	32.0	3.8	2.5	60
6	.2	11.3	7.0	1.15	36.8	1.8	1.2	3	7	5.7	2.95	26.7	6.3	5.6	51
									a3	4.8	1.56	33.3	2.7	3.2	61
7	.2	14.0	6.8	1.25	37.0	1.9	1.0	-4	7	4.1	2.35	28.2	4.8	4.5	66
8	.2	14.0	7.0	1.08	37.1	1.7	.9	-10	3	4.0	2.76	33.0	4.8	4.6	81
9	.2	14.3	7.1	1.10	36.9	1.7	2.2	13	3	5.0	2.84	32.5	5.0	5.1	68
10	.2	13.8	7.0	1.00	37.1	1.5	1.2	5	5	3.8	2.29	30.7	4.3	4.3	45
11	.2	13.6	7.5	1.26	38.5	1.9	2.0	12	5	4.1	3.90	31.2	7.1	5.5	91
12	.2	14.8	7.6	1.26	38.6	1.9	1.3	8	4	4.5	3.68	32.5	6.4	6.3	82
13	.2	14.0	7.7	1.28	38.8	1.9	.4	0	3	4.4	3.36	33.2	5.8	6.3	88
14	.2	14.0	7.7	1.37	38.5	2.0	1.4	2	7	3.4	2.48	27.9	5.1	3.0	62
15	.2	17.9	7.9	1.18	38.0	1.8	1.1	5	6	4.5	2.17	33.5	3.7	3.8	56
16	.2	17.1	7.8	1.28	38.2	1.9	1.6	0	5	6.9	3.47	29.5	6.7	3.2	32
17	.2	17.9	7.9	1.25	38.0	1.9	1.2	0	6	5.6	3.72	29.5	7.2	3.1	48
18	.2	18.2	7.8	1.23	38.3	1.8	1.3	8	5	5.4	3.59	30.0	6.8	2.7	40
19	.2	18.1	7.9	1.28	38.0	1.9	1.5	18	2	5.2	2.50	35.0	4.1	2.8	32
20	.2	16.9	7.9	1.03	38.0	1.6	.9	0	3	4.6	4.10	33.0	7.1	5.2	60
21	.2	19.7	7.8	1.14	37.7	1.7	1.2	10	3	5.4	1.40	33.0	2.4	2.3	36
22	.2	18.7	7.9	1.22	38.5	1.8	1.8	13	4	5.3	3.30	32.0	5.9	2.7	27
23	.2	19.9	7.9	1.05	38.0	1.6	.6	0	4	4.9	4.10	29.9	7.8	3.4	50
24	.2	20.1	7.8	1.26	38.0	1.9	1.7	6	3	5.1	4.13	33.3	7.1	3.0	34
25	.2	19.2	7.8	1.29	37.9	1.9	1.4	17	3	4.9	3.84	32.6	6.7	3.4	45
26	.2	20.4	7.8	1.20	38.3	1.8	1.6	9	3	6.5	3.10	33.9	5.6	3.2	35
27	.4	15.8	7.4	1.07	36.3	1.7	3.4	36	3	3.9	4.30	31.3	7.8	7.4	102
28	.4	15.4	7.0	1.00	36.7	1.6	3.4	40	6	4.6	4.96	24.8	11.3	5.6	29
									a4	2.4	3.18	29.4	6.2	3.2	78
29	.4	15.6	7.5	1.02	37.0	1.6	2.1	9	3	3.0	3.13	32.6	5.5	5.4	93
30	.4	15.7	7.8	.68	36.2	1.1	3.3	37	5	4.2	3.91	27.0	8.2	6.7	108
31	.4	15.7	7.9	1.03	38.8	1.5	.5	-10	3	5.5	2.80	35.1	4.6	6.6	83
									a6	3.7	2.99	30.8	5.5	4.2	95
32	.4	15.4	7.9	1.15	38.9	1.7	3.3	32	5	5.1	3.89	28.2	7.9	7.7	134
33	.4	15.5	8.0	1.05	38.8	1.6	0	-10	6	5.5	4.12	30.6	7.7	8.2	110
34	.4	15.2	7.5	1.24	38.2	1.9	0	-10	3	5.6	3.38	32.5	5.9	6.4	89
35	.4	16.9	8.5	1.17	37.4	1.8	1.5	40	3	8.0	1.68	33.2	3.2	5.9	100
36	.4	16.7	8.7	1.09	38.2	1.6	2.4	24	5	8.0	3.55	28.5	7.1	7.1	84
									a3	6.2	3.82	33.2	6.6	6.3	96
37	.4	16.8	8.8	1.19	37.8	1.8	1.4	2	5	6.2	4.11	28.7	8.2	6.8	93
38	.4	17.3	9.1	1.12	37.5	1.7	1.4	2	4	7.1	4.71	30.9	8.7	8.5	127
39	.4	16.8	9.2	1.14	37.7	1.7	.3	-10	2	8.0	2.88	34.5	4.8	6.6	77
									a5	8.4	3.88	26.7	8.3	6.6	114
40	.4	19.5	8.3	.98	37.4	1.5	3.9	24	4	5.2	4.67	31.5	8.4	8.8	94
41	.4	20.1	8.4	1.01	37.0	1.6	3.9	49	4	5.5	4.09	27.8	8.4	4.0	49
42	.4	19.7	8.3	1.20	37.7	1.8	1.6	5	5	6.2	3.32	30.5	6.2	5.1	61
43	.4	19.4	7.4	1.00	38.3	1.5	4.3	56	3	4.9	2.51	31.6	4.5	5.2	48
44	.4	18.7	7.9	1.02	37.8	1.5	3.8	41	2	6.2	3.01	34.0	5.1	5.1	53
									a4	2.5	3.40	30.1	6.4	4.1	89
45	.4	19.2	10.3	.96	37.9	1.4	2.7	22	2	8.6	2.75	34.0	4.6	4.8	80
46	.4	20.2	---	.98	37.9	1.5	1.1	0	6	---	3.62	28.8	7.2	4.5	85
47	.4	19.7	---	1.11	37.2	1.7	5.1	57	1	---	1.11	37.2	1.7	5.1	57
									a3	---	2.23	32.1	4.0	4.1	73
48	.4	19.5	---	1.14	37.2	1.8	3.4	37	3	---	4.54	29.6	8.7	5.5	65
									a2	---	3.16	33.2	5.4	3.2	78
49	.4	20.0	7.7	1.14	36.1	1.8	5.2	80	4	5.8	4.88	26.5	10.4	4.6	90
50	.4	20.0	7.8	1.02	35.5	1.6	4.2	59	3	5.6	4.54	28.7	9.0	9.2	129
51	.4	20.4	7.7	1.23	36.0	2.0	1.8	9	4	7.2	3.70	27.8	7.6	4.9	69
52	.4	20.0	7.8	1.12	36.8	1.7	1.7	10	3	4.7	2.43	33.3	4.2	5.2	71
53	.4	19.9	8.0	.96	37.7	1.5	.4	-9	2	5.0	3.48	33.5	5.9	7.4	110
									a3	3.9	4.36	30.5	8.1	6.7	120
54	.4	19.9	7.9	1.14	37.5	1.7	1.9	13	4	4.5	5.39	29.5	10.4	8.7	130
55	.4	22.8	8.7	1.03	37.0	1.6	3.8	50	1	8.7	1.03	37.0	1.6	3.8	50
56	.4	---	8.9	1.03	37.0	1.6	.7	-15	4	5.3	4.49	28.5	9.0	5.9	92
57	.4	22.6	8.0	1.08	37.2	2.2	1.2	-4	5	5.7	4.30	28.4	8.6	6.5	71
58	.4	22.8	8.1	.98	36.7	1.5	1.4	-11	3	3.5	2.37	34.0	4.0	3.8	71
59	.4	22.9	8.8	1.15	36.8	1.8	2.1	14	4	4.8	4.53	27.6	9.3	6.4	104
60	.4	22.7	7.8	1.19	36.7	1.8	3.0	28	4	6.1	5.64	26.8	11.9	4.7	48
61	.4	25.7	8.8	1.12	37.5	1.7	.7	-10	2	4.4	1.95	36.8	3.0	3.6	50
62	.4	25.4	8.6	.94	36.8	1.5	1.5	-6	4	6.5	3.36	31.1	6.1	3.2	33
									a3	3.9	2.28	34.0	3.8	2.4	44

[a]Impact for maximum angular acceleration.

NACA

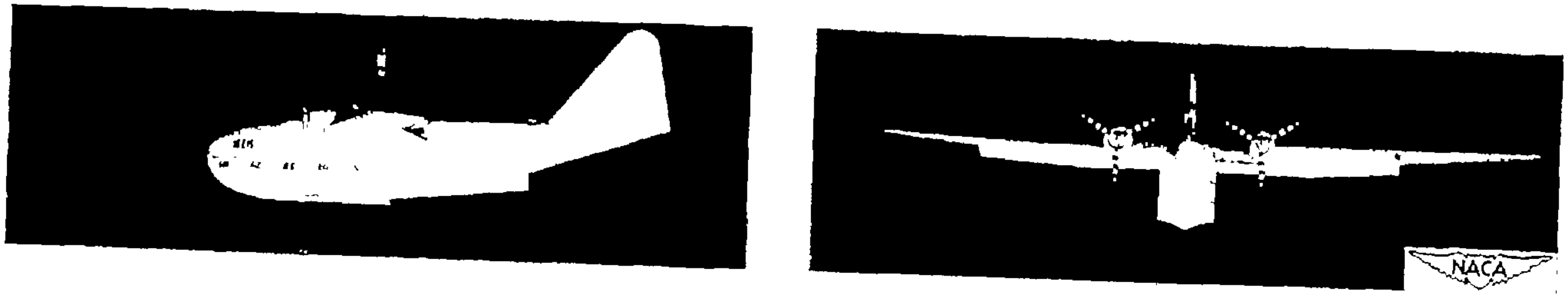
TABLE III - Concluded

DATA OBTAINED DURING LANDINGS IN WAVES - Concluded

Landing	Wave height (ft)	Wave length (ft)	Initial impact						Maximum acceleration						
			τ_L (deg)	V_v (fps)	V_h (fps)	γ (deg)	n_v (g)	α $\left(\frac{\text{radians}}{\text{sec}^2}\right)$	Impact	τ (deg)	V_v (fps)	V_h (fps)	γ (deg)	n_v (g)	α $\left(\frac{\text{radians}}{\text{sec}^2}\right)$
63	0.4	25.4	8.7	1.00	36.8	1.6	2.0	29	3	4.5	3.66	30.0	6.9	4.9	78
64	.4	25.7	9.5	1.14	36.0	1.8	1.0	-18	3	6.1	4.20	28.8	8.3	3.7	48
65	.4	----	9.0	1.27	36.4	2.0	1.4	-10	9	6.8	4.04	24.1	9.5	3.9	51
66	.4	25.7	8.0	1.08	39.3	1.6	2.4	28	3	5.7	3.94	32.0	7.0	5.4	73
67	.4	25.6	7.9	1.09	38.1	1.6	1.9	10	6	6.2	3.97	25.8	8.7	3.6	57
68	.4	25.7	7.8	1.10	38.5	1.6	1.8	7	6	6.7	3.82	25.1	8.6	3.2	45
69	.4	26.6	7.9	1.25	38.2	1.9	2.1	24	4	5.0	4.45	29.7	8.5	5.0	90
70	.4	32.4	9.1	1.02	35.8	1.6	.8	-9	3	7.3	3.25	31.7	5.9	2.4	16
									[a]2	4.7	1.79	34.8	2.9	1.7	23
71	.4	32.8	9.0	1.03	36.4	1.6	1.0	9	3	6.0	3.00	29.4	5.8	2.3	23
72	.4	34.1	8.8	1.13	36.5	1.8	.6	-10	5	5.4	3.44	26.0	7.5	3.2	45
73	.4	34.2	7.9	1.22	38.4	1.8	2.0	13	6	6.4	3.94	27.0	8.3	3.0	40
74	.4	34.5	9.0	1.29	38.6	1.9	1.9	21	4	4.8	3.37	31.1	6.2	3.1	37
75	.4	34.8	8.2	1.23	38.0	1.9	1.2	20	2	7.7	3.78	34.4	6.3	2.6	14
									[a]7	5.5	4.10	25.6	9.1	2.2	32
76	.4	33.5	8.0	1.27	37.9	1.9	2.1	13	4	6.4	2.75	30.7	5.1	3.4	44
77	.4	34.8	7.9	1.09	38.2	1.6	1.5	10	3	5.8	3.90	32.8	6.8	3.4	44
78	.4	32.0	7.9	1.03	38.8	1.5	1.0	-6	3	4.4	2.94	33.0	5.1	3.1	38
									[a]5	5.0	3.92	27.9	8.0	2.6	45
79	.4	32.5	7.9	1.05	37.6	1.6	.2	3	3	6.0	3.36	30.7	6.2	2.8	33
80	.6	21.9	8.2	1.03	36.0	1.6	2.2	13	4	5.1	4.44	27.6	9.2	4.9	97
81	.6	21.8	8.3	.99	37.3	1.5	1.3	0	3	6.3	1.81	33.9	3.0	4.7	60
82	.6	22.2	---	.92	37.1	1.4	.9	0	3	---	4.01	31.4	7.3	8.0	106
83	.6	22.8	7.7	.97	37.8	1.5	2.4	24	9	7.9	3.56	23.0	8.6	3.6	53
84	.6	22.7	7.7	.97	38.2	1.5	3.6	56	2	5.2	3.29	34.0	5.6	6.8	100
85	.6	22.2	7.6	.75	38.2	1.1	1.4	6	4	6.0	1.88	33.9	3.2	4.2	63
									[a]6	3.6	4.15	29.1	8.1	3.8	92
86	.6	21.2	7.8	.91	38.0	1.4	1.4	9	4	4.8	5.42	30.5	10.1	7.8	110
87	.6	24.1	7.8	.88	36.8	1.4	.9	0	4	5.1	3.87	31.5	7.0	5.2	101
88	.6	24.1	8.3	.82	37.1	1.3	1.7	7	5	5.4	4.12	29.4	8.0	7.6	113
89	.6	24.3	8.3	.94	37.4	1.4	.6	10	4	6.5	4.32	28.4	8.6	8.7	133
90	.6	23.6	8.2	.86	37.5	1.3	2.3	19	4	6.7	4.20	28.7	8.3	6.7	120
91	.6	25.0	8.3	.88	37.0	1.4	.6	4	4	6.7	4.90	26.9	10.3	9.3	126
92	.6	24.3	7.5	1.08	38.9	1.6	3.2	30	5	2.9	4.62	29.2	9.0	6.7	118
93	.6	24.6	7.5	.99	38.4	1.5	1.7	8	8	4.6	3.88	23.1	9.5	7.0	114
94	.6	25.1	7.9	.87	37.0	1.3	0	-10	2	5.2	3.38	33.5	5.8	6.6	108
95	.6	25.6	8.0	1.04	37.4	1.6	4.3	60	4	5.9	4.22	29.0	8.3	4.8	57
									[a]3	3.5	3.03	31.2	5.6	4.1	61
96	.6	25.7	8.0	.92	37.6	1.4	3.2	46	2	6.1	3.52	34.1	5.9	7.7	108
									[a]4	5.9	4.62	28.9	9.1	7.4	133
97	.6	25.2	8.1	.97	37.4	1.5	3.9	58	2	4.9	4.14	33.8	7.0	7.4	110
98	.6	25.1	8.1	.93	37.1	1.4	1.1	-3	4	6.9	5.46	28.2	11.0	9.0	151
99	.6	25.6	8.1	1.00	36.9	1.6	2.5	10	2	7.2	1.71	34.0	2.9	5.5	80
100	.6	25.6	7.7	.95	38.3	1.4	.3	-6	6	6.0	4.34	24.1	10.2	4.8	82
101	.6	26.3	7.7	.92	38.5	1.4	3.6	76	4	4.0	5.00	29.7	9.6	8.6	138
102	.6	31.1	8.0	.90	37.1	1.4	2.9	37	5	3.7	4.06	26.5	8.7	6.4	100
103	.6	29.6	8.0	.90	37.6	1.4	.6	-6	3	4.3	4.87	30.9	9.0	6.7	97
104	.6	28.6	8.0	.95	37.8	1.4	1.0	0	4	4.7	3.73	32.5	6.5	6.6	85
105	.6	29.4	7.9	1.01	37.4	1.5	1.5	6	6	4.2	4.28	25.9	9.4	6.1	90
106	.6	28.6	8.0	.94	38.1	1.4	.4	-11	3	3.8	5.32	31.6	9.6	8.4	123
107	.6	28.1	8.1	1.03	37.0	1.6	2.3	16	3	4.2	4.46	31.3	8.1	6.5	94
108	.6	30.1	7.7	.75	40.0	1.1	1.7	5	4	5.8	5.15	31.6	9.3	7.5	106
109	.6	30.0	7.7	.81	40.0	1.2	1.8	15	6	4.8	4.33	27.2	9.0	6.0	88
									[a]8	5.2	4.47	24.3	10.4	5.8	93
110	.6	30.7	7.8	1.10	38.0	1.7	1.8	13	3	5.0	---	32.0	---	3.8	57
111	.6	29.1	7.8	.95	37.5	1.4	2.0	11	2	5.0	3.24	34.2	5.4	3.0	42
112	.6	31.7	7.8	.88	37.5	1.3	2.8	36	2	4.1	3.61	33.8	6.1	4.4	74
113	.6	30.7	7.9	.98	37.7	1.5	1.3	8	6	3.2	4.83	26.2	10.4	5.7	94
114	.6	29.0	7.9	.90	37.9	1.4	2.1	30	8	5.0	3.97	23.8	9.5	4.6	74
115	.6	41.1	7.6	.97	37.7	1.5	1.7	9	6	3.8	4.75	26.6	10.1	3.4	57
116	.6	39.8	7.6	.93	38.5	1.6	0	-7	5	5.3	3.62	27.9	7.4	4.9	65
117	.6	39.3	7.5	.82	38.5	1.2	.8	0	5	2.5	4.51	27.6	9.3	5.2	82
118	.6	38.8	7.5	1.12	38.6	1.7	2.7	0	4	3.6	4.40	30.2	8.3	6.7	78
119	.6	38.9	7.5	.93	38.2	1.4	1.4	6	6	3.5	4.43	27.1	9.3	4.3	63
120	.6	38.6	7.6	.92	38.3	1.4	.9	-8	6	5.6	5.03	27.2	10.5	6.5	86
121	.6	45.6	7.5	1.02	38.1	1.5	1.2	7	6	2.6	5.03	27.4	10.4	5.0	80
122	.6	45.8	7.5	.97	38.6	1.4	1.7	28	5	2.9	4.86	26.8	10.3	4.0	71
123	.6	46.0	7.9	.95	38.5	1.4	2.0	33	4	3.2	5.00	30.4	9.3	6.1	85
124	.6	47.5	8.0	1.02	37.5	2.2	1.0	-5	5	4.5	4.54	28.8	8.9	5.4	72
125	.6	45.0	8.0	.92	37.0	1.4	1.1	5	4	1.5	4.74	30.4	8.9	4.5	85

[a]Impact for maximum angular acceleration.

(a) Hull of $\frac{L}{b} = 15$.



(b) Hull of $\frac{L}{b} = 6$.

Figure 1.- Hull length-beam ratio models.

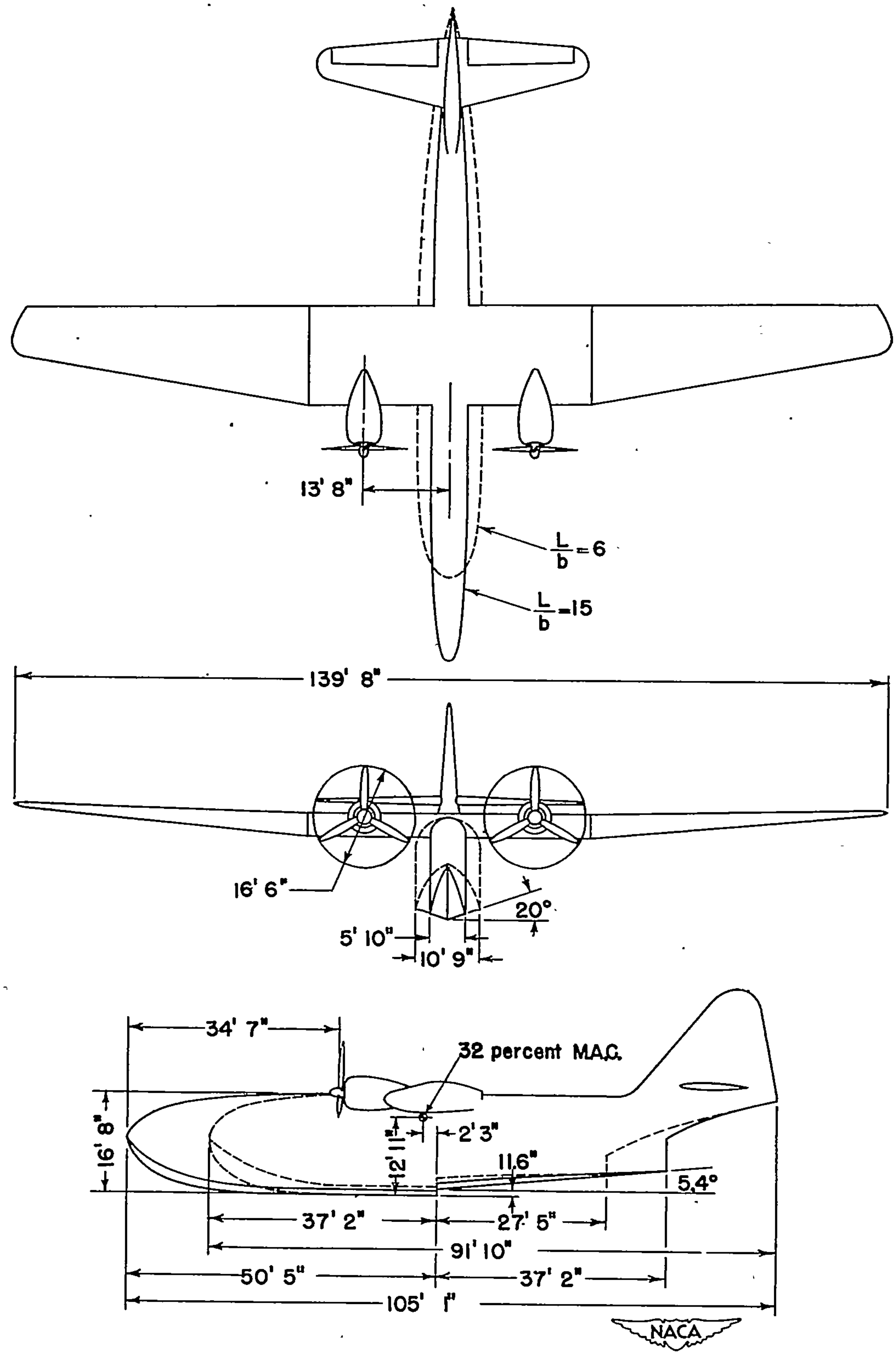
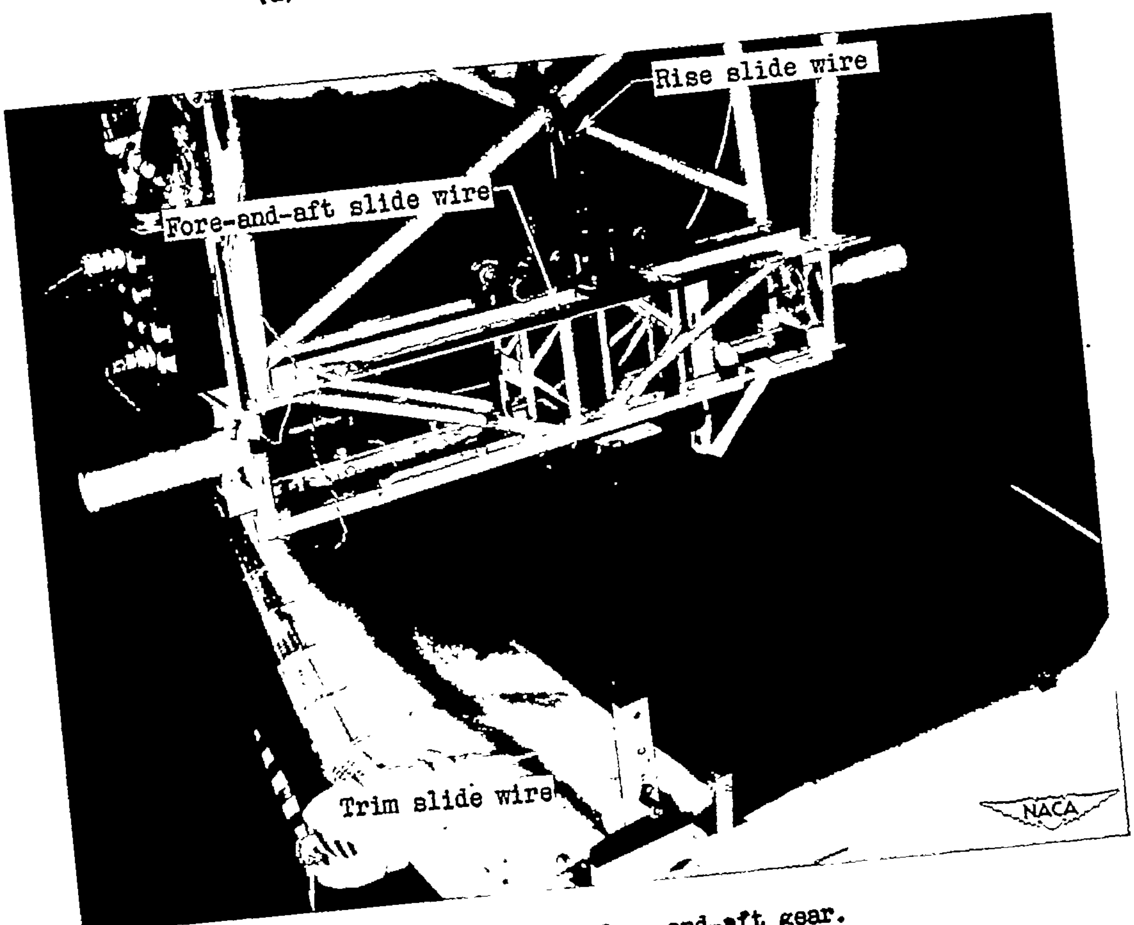


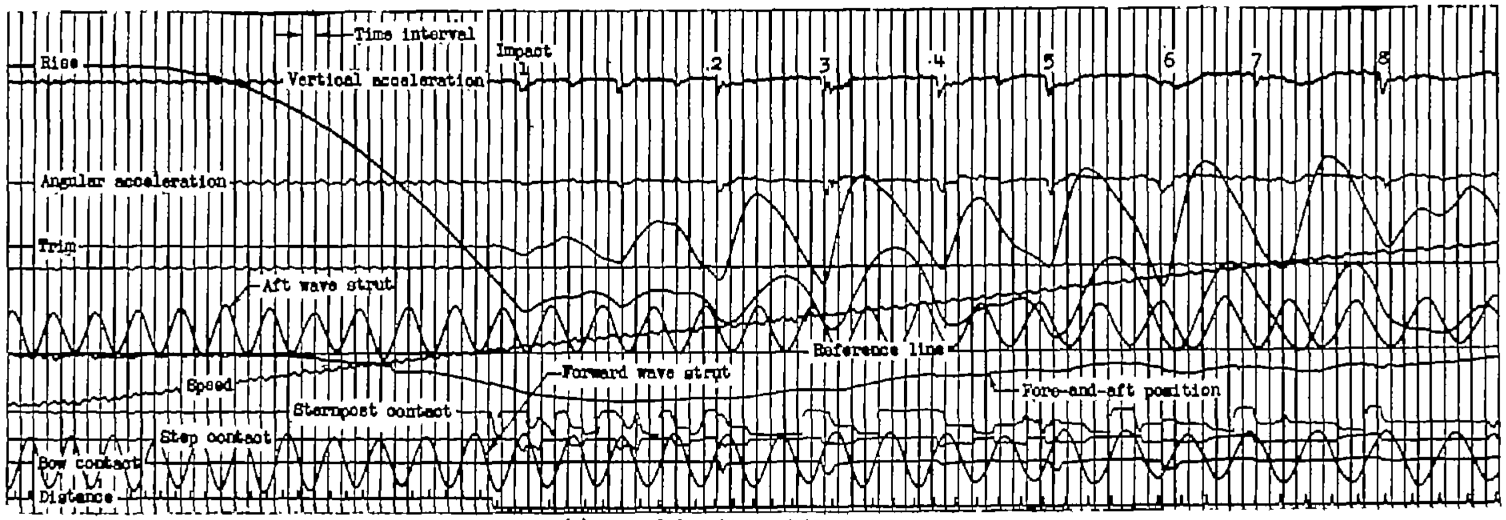
Figure 2.- General arrangement.

(a) Setup of model on towing apparatus.

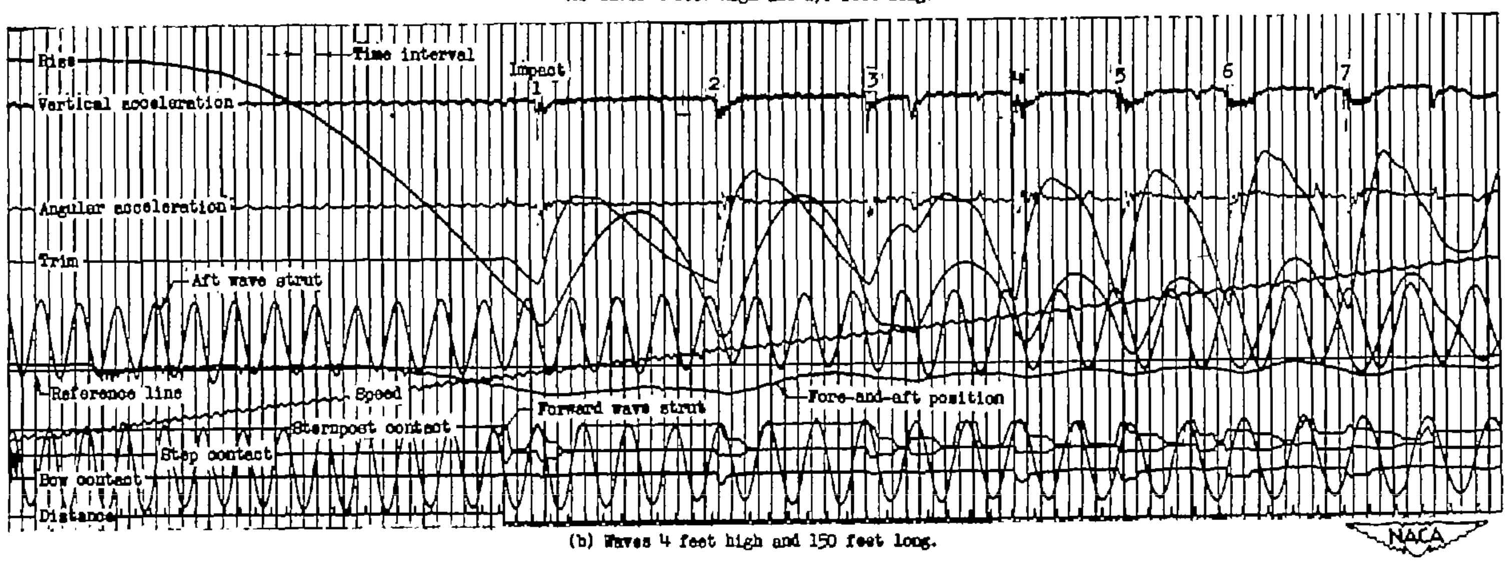


(b) Details of fore-and-aft gear.

Figure 3.- Model and towing apparatus.

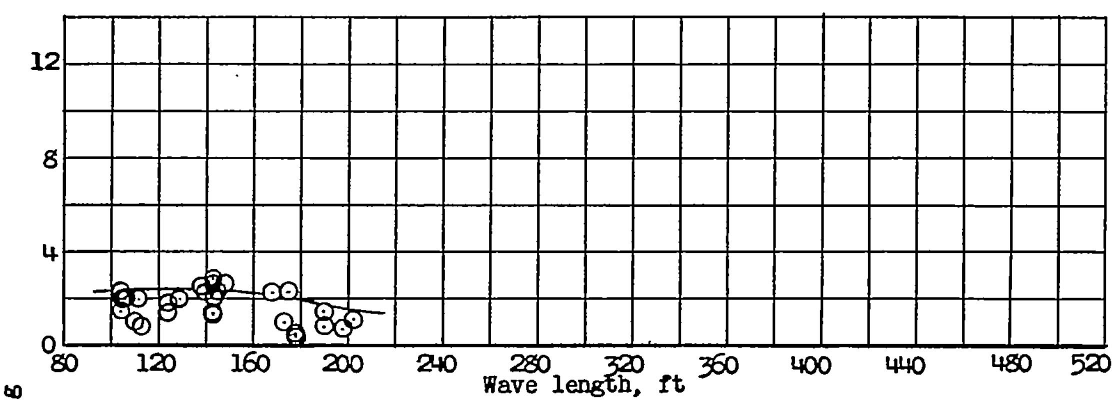


(a) Waves 2 feet high and 170 feet long.

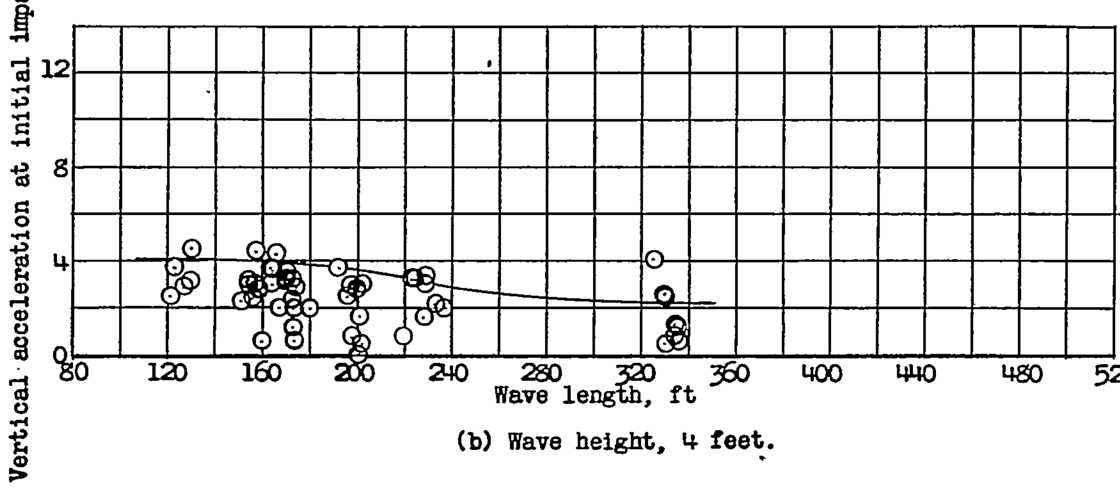


(b) Waves 4 feet high and 150 feet long.

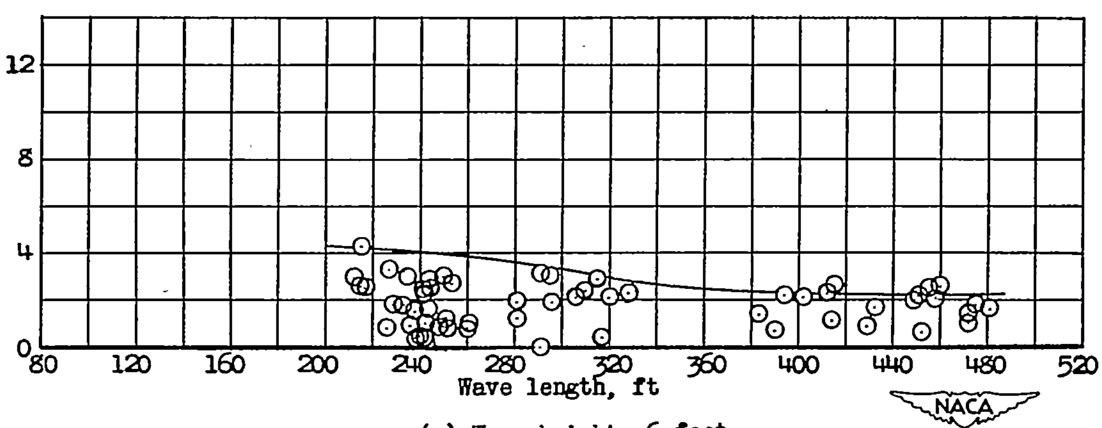
Figure 4.- Typical records made during landings in waves.



(a) Wave height, 2 feet.



(b) Wave height, 4 feet.



(c) Wave height, 6 feet.

Figure 5.- Variation of vertical acceleration at initial impact with wave length. Length-beam ratio, 6.

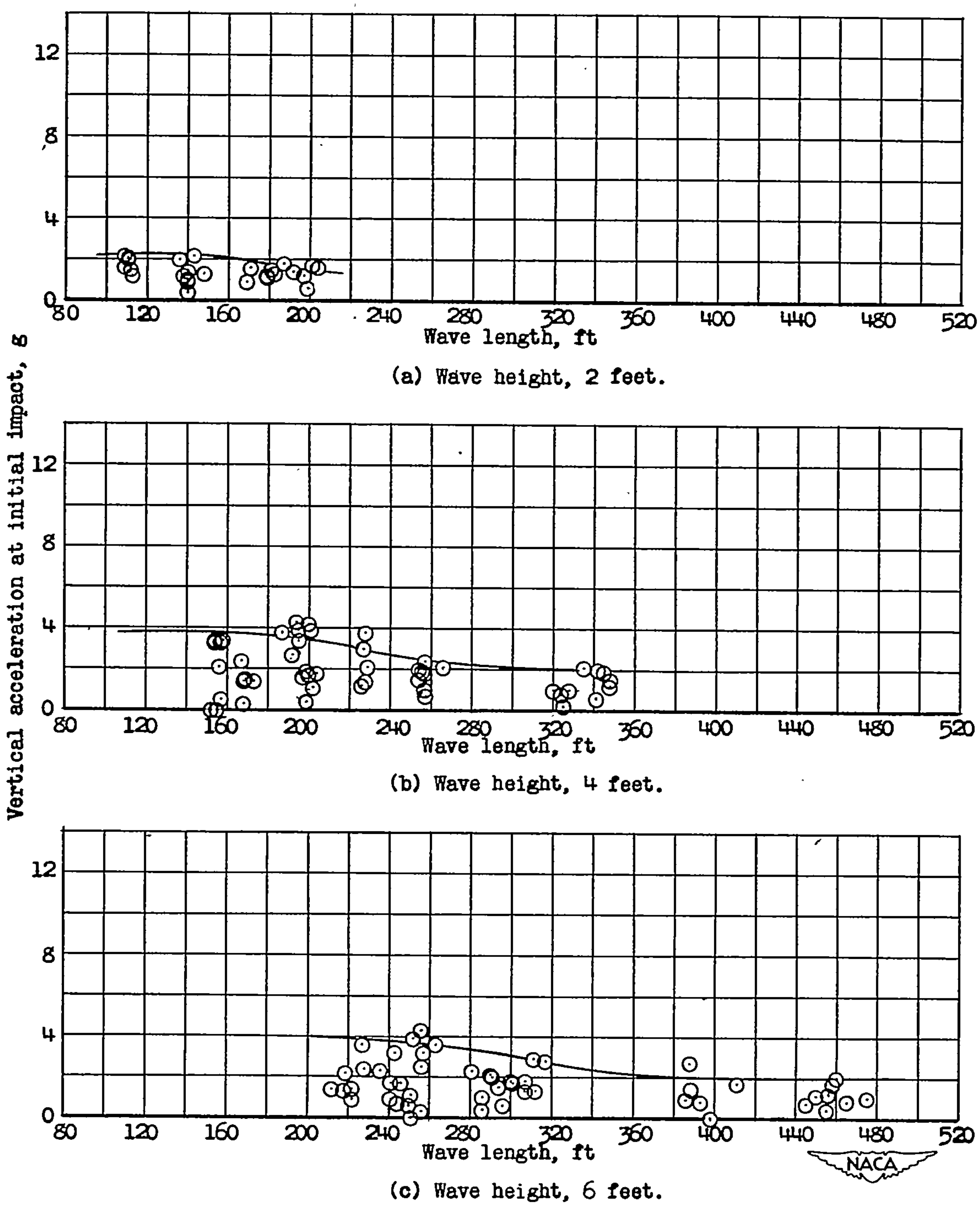
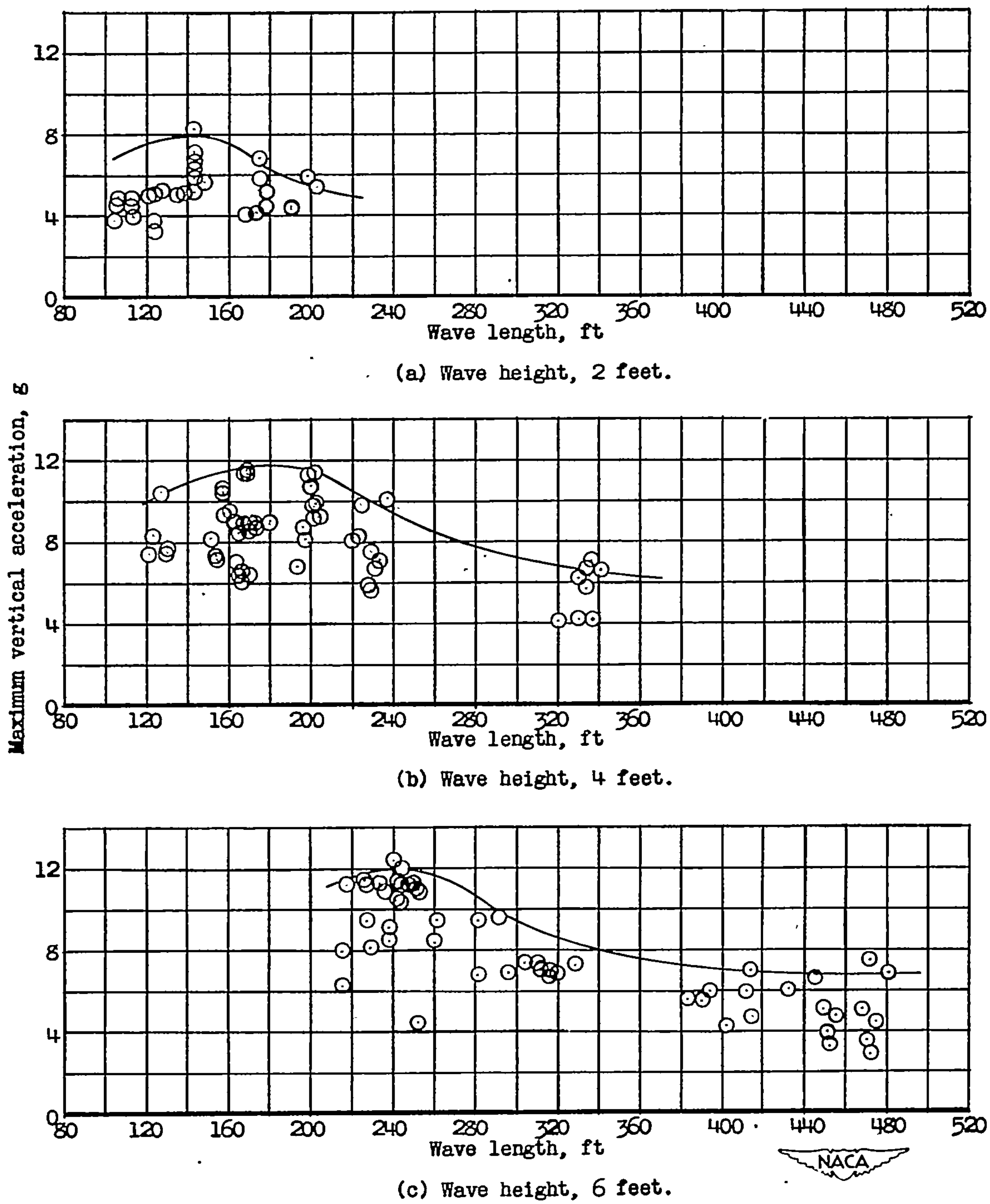


Figure 6.- Variation of vertical acceleration at initial impact with wave length. Length-beam ratio, 15.

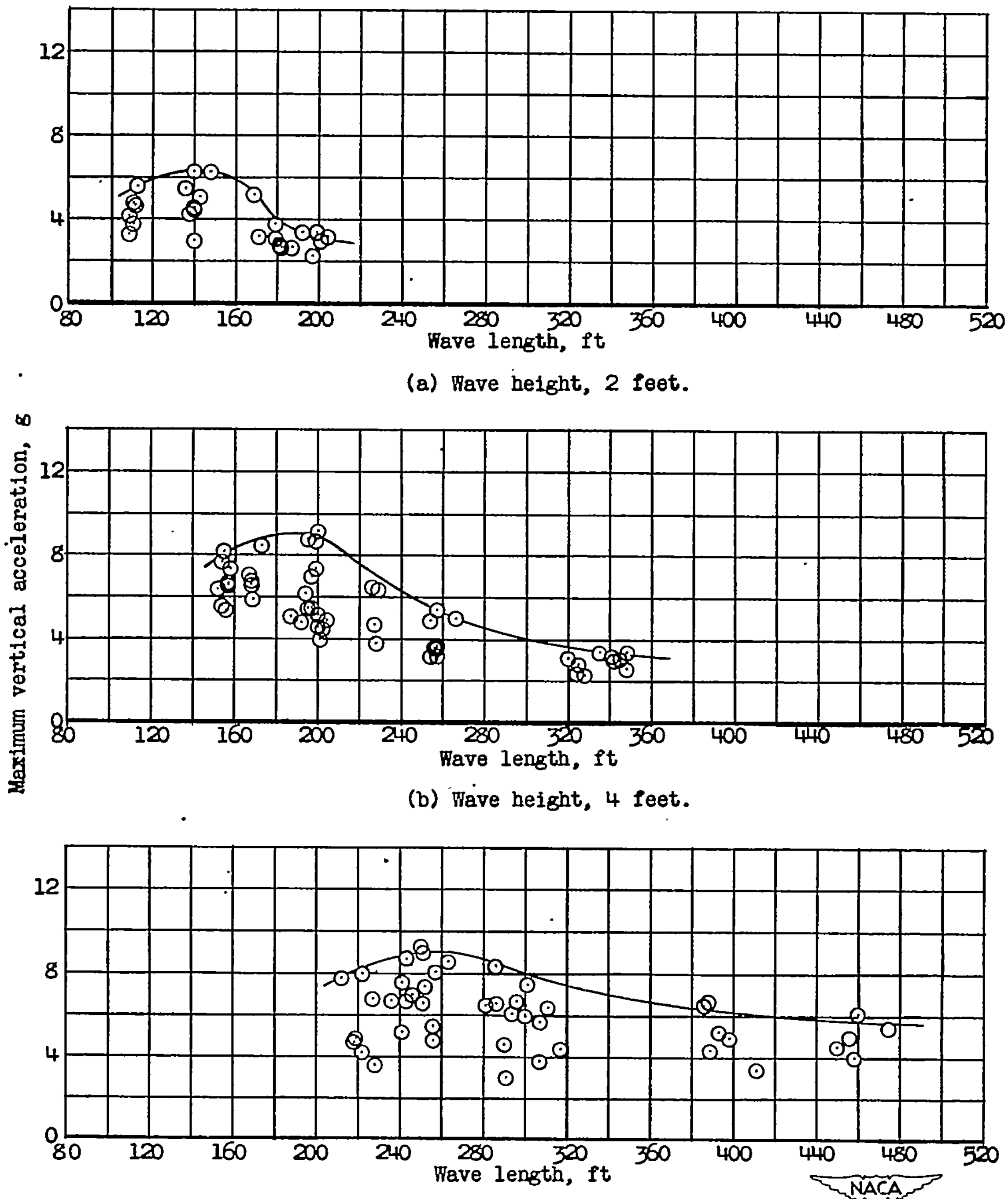


(a) Wave height, 2 feet.

(b) Wave height, 4 feet.

(c) Wave height, 6 feet.

Figure 7.- Variation of maximum vertical acceleration with wave length. Length-beam ratio, 6.

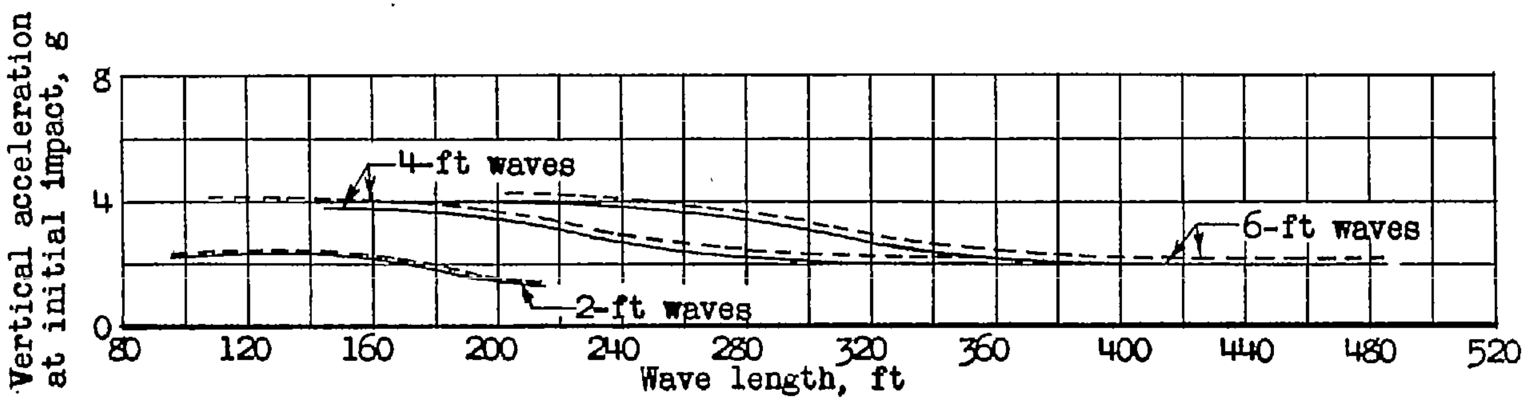


(a) Wave height, 2 feet.

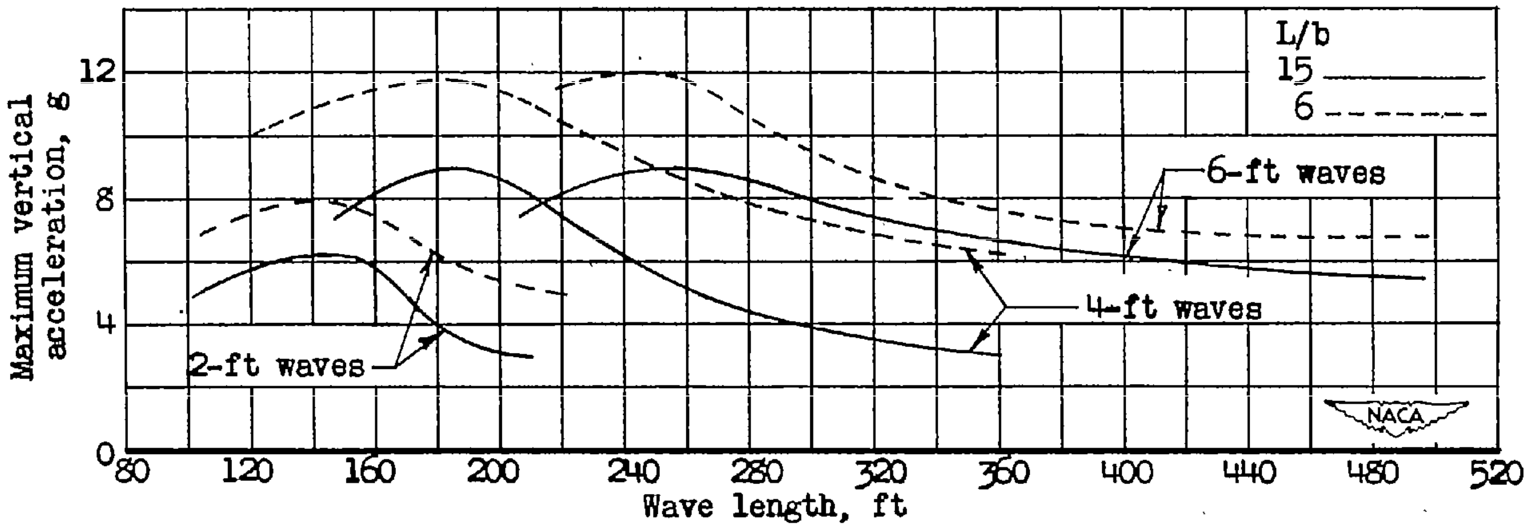
(b) Wave height, 4 feet.

(c) Wave height, 6 feet.

Figure 8.- Variation of maximum vertical acceleration with wave length. Length-beam ratio, 15.

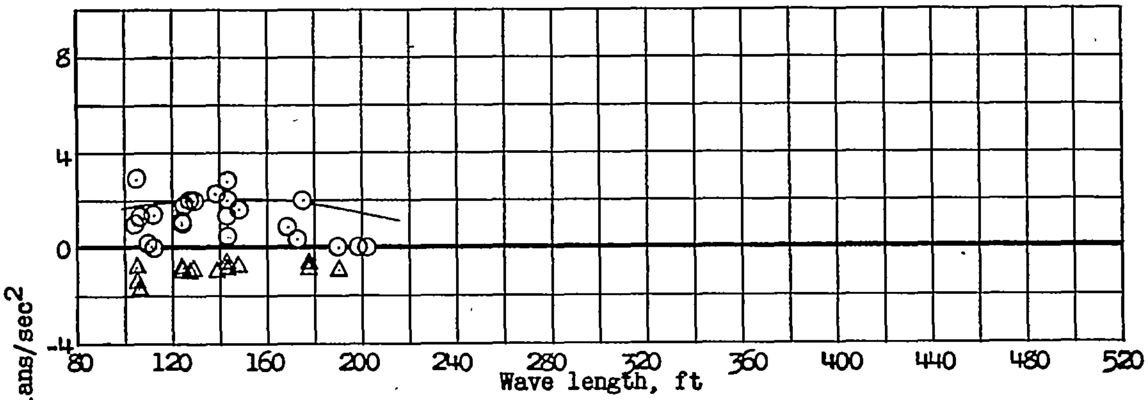


(a) Acceleration at initial impact.

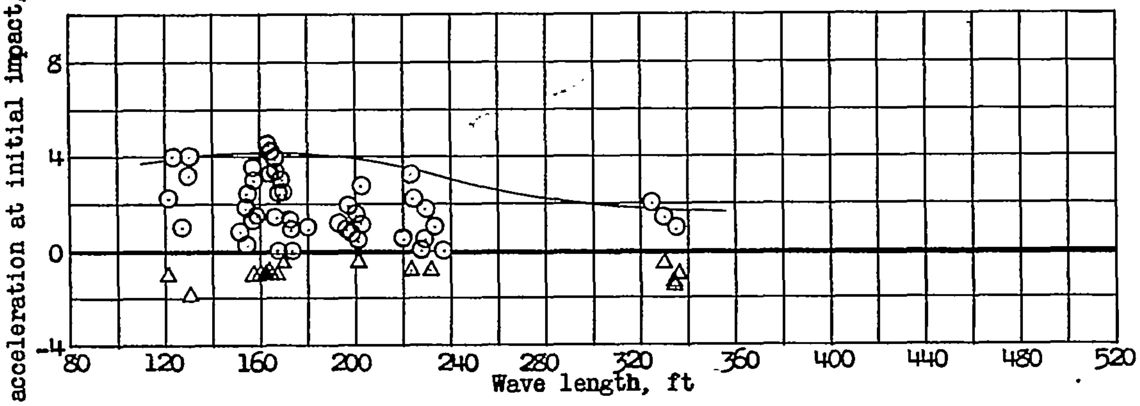


(b) Maximum acceleration.

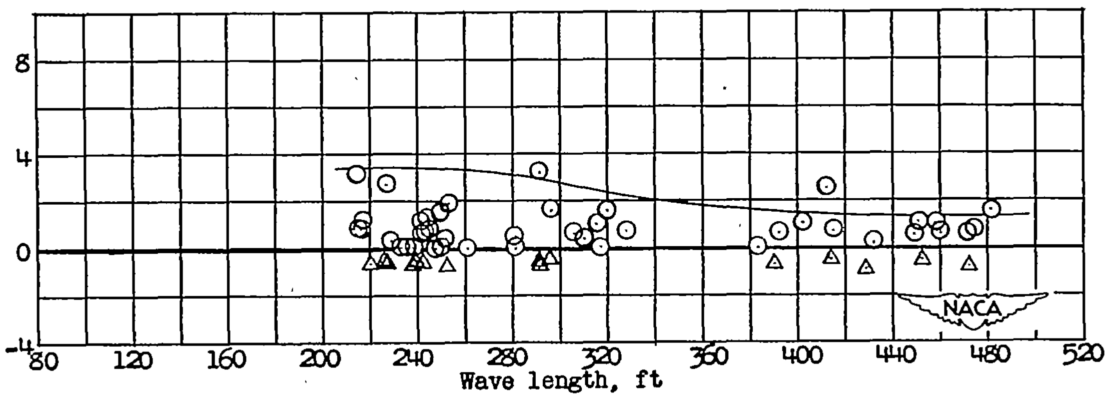
Figure 9.- Effect of length-beam ratio on vertical accelerations.



(a) Wave height, 2 feet.

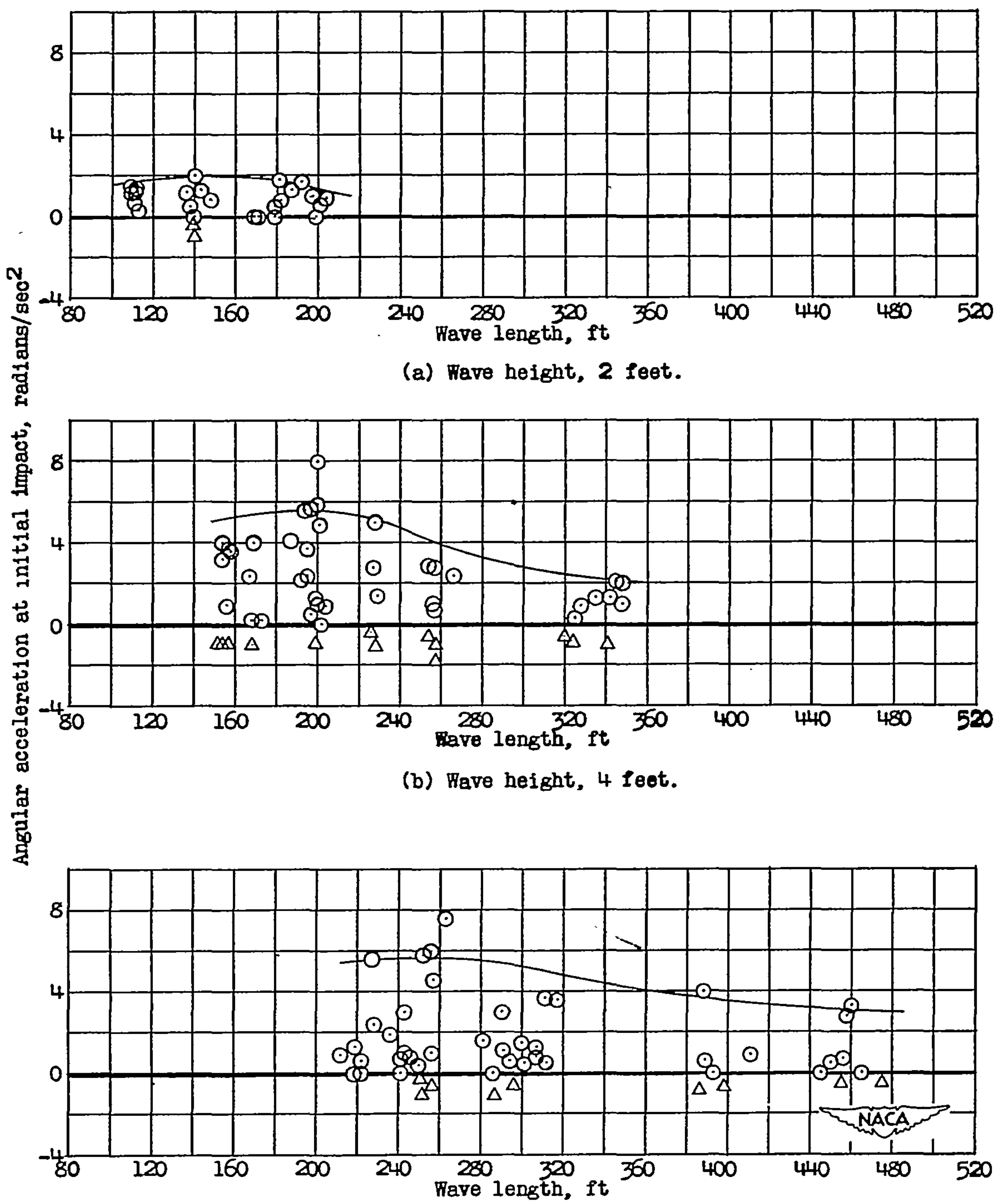


(b) Wave height, 4 feet.



(c) Wave height, 6 feet.

Figure 10.- Variation of angular acceleration at initial impact with wave length. Length-beam ratio, 6.

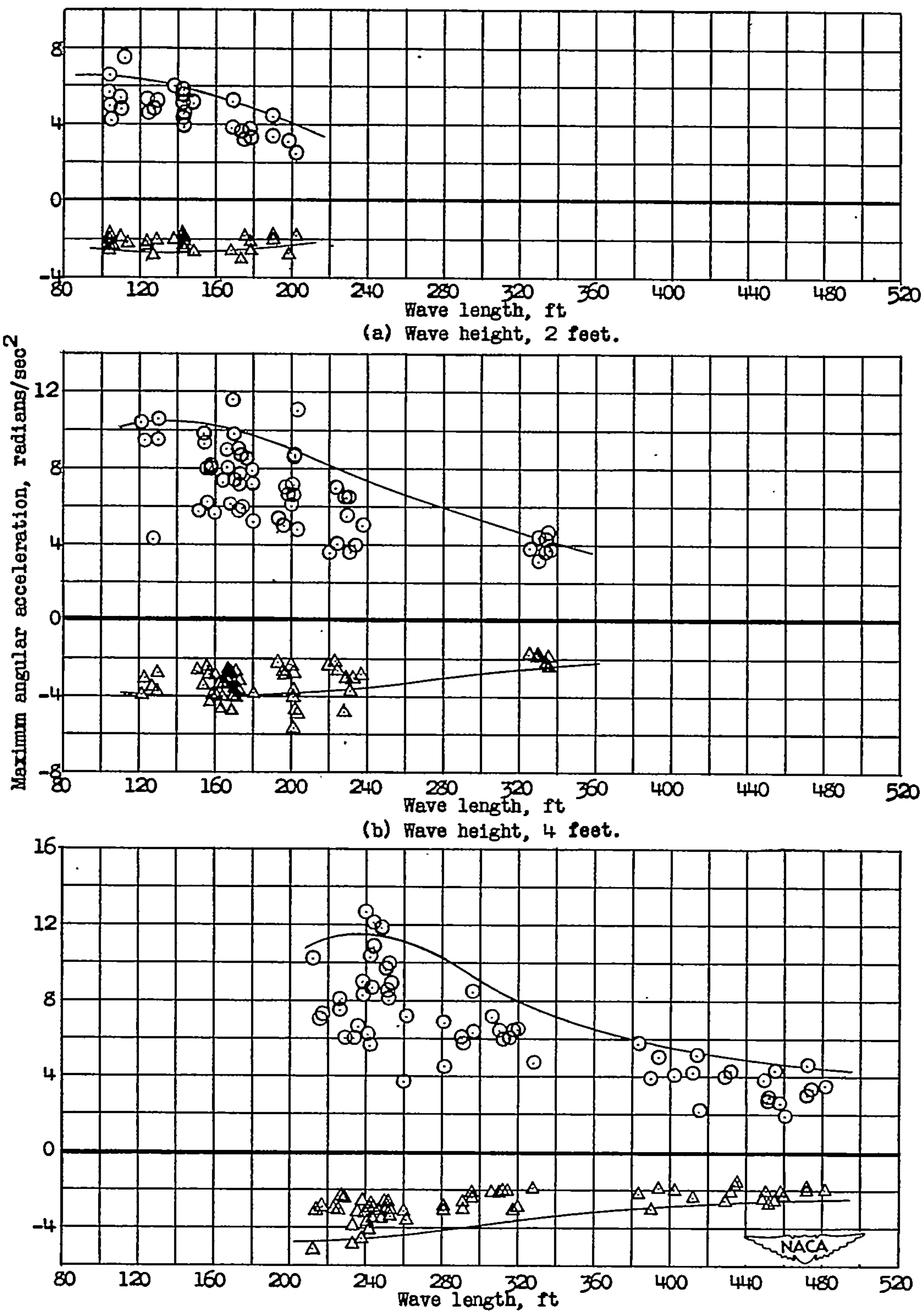


(a) Wave height, 2 feet.

(b) Wave height, 4 feet.

(c) Wave height, 6 feet.

Figure 11.- Variation of angular acceleration at initial impact with wave length. Length-beam ratio, 15.

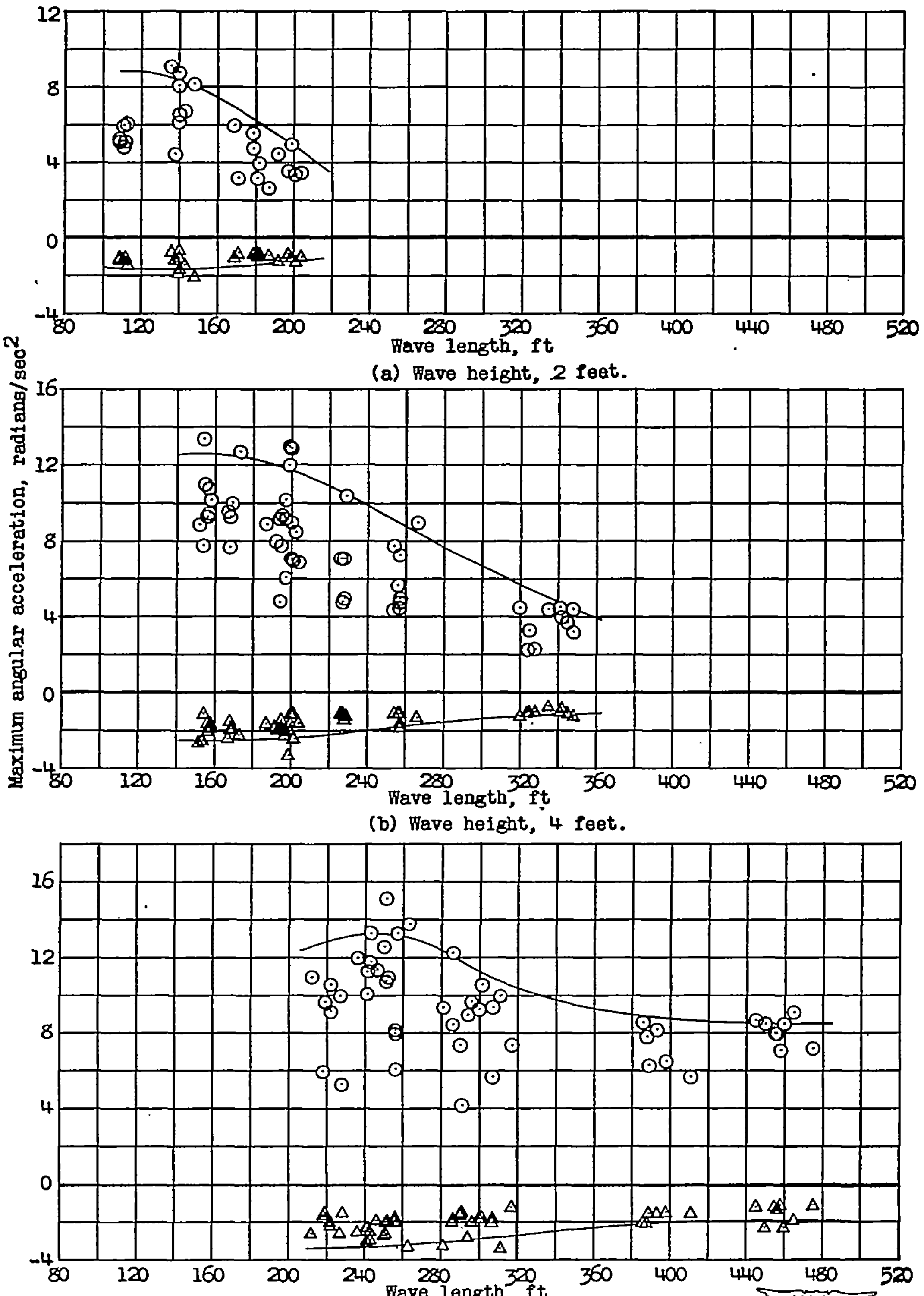


(a) Wave height, 2 feet.

(b) Wave height, 4 feet.

(c) Wave height, 6 feet.

Figure 12.- Variation of maximum angular acceleration with wave length. Length-beam ratio, 6.

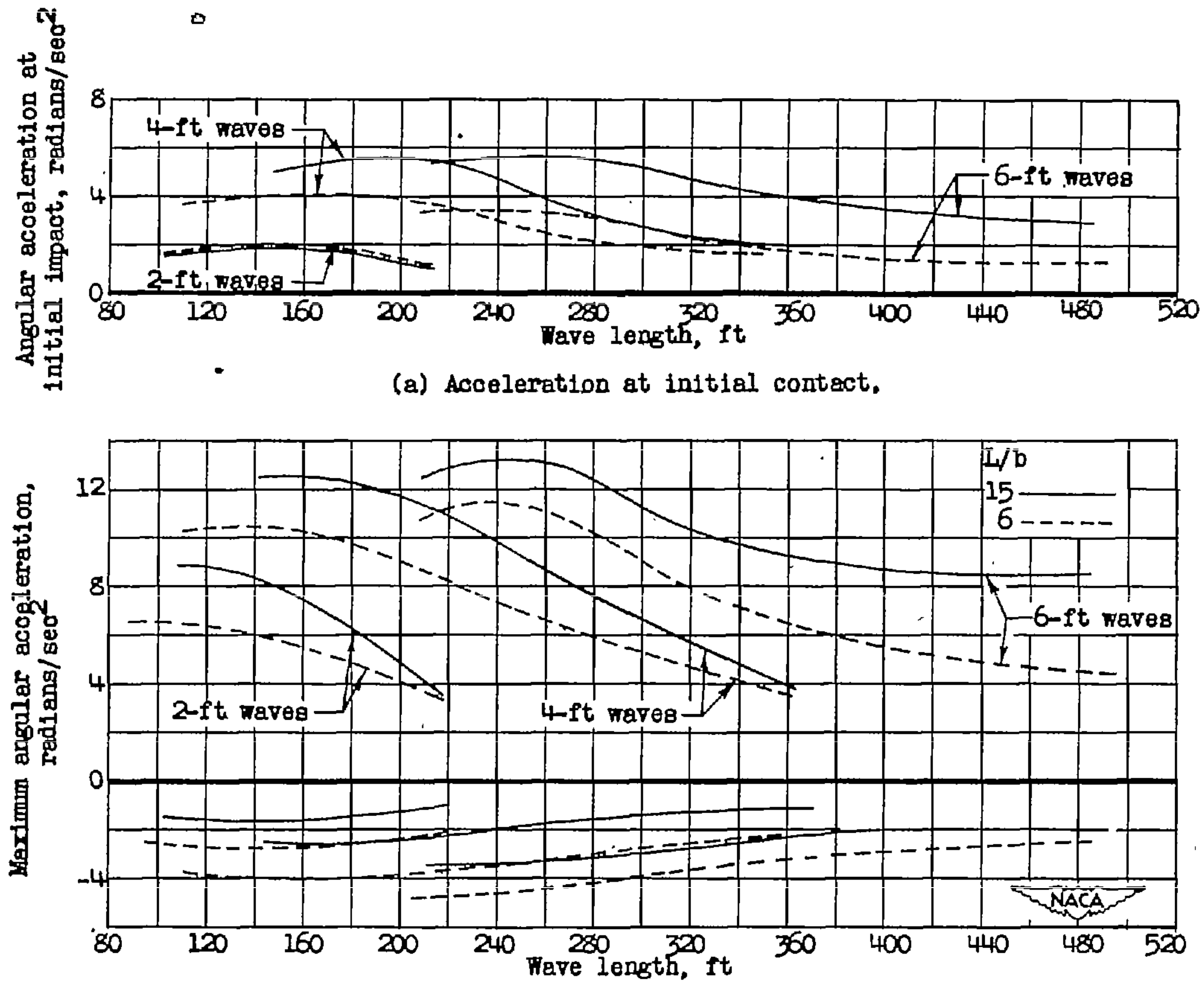


(a) Wave height, 2 feet.

(b) Wave height, 4 feet.

(c) Wave height, 6 feet.

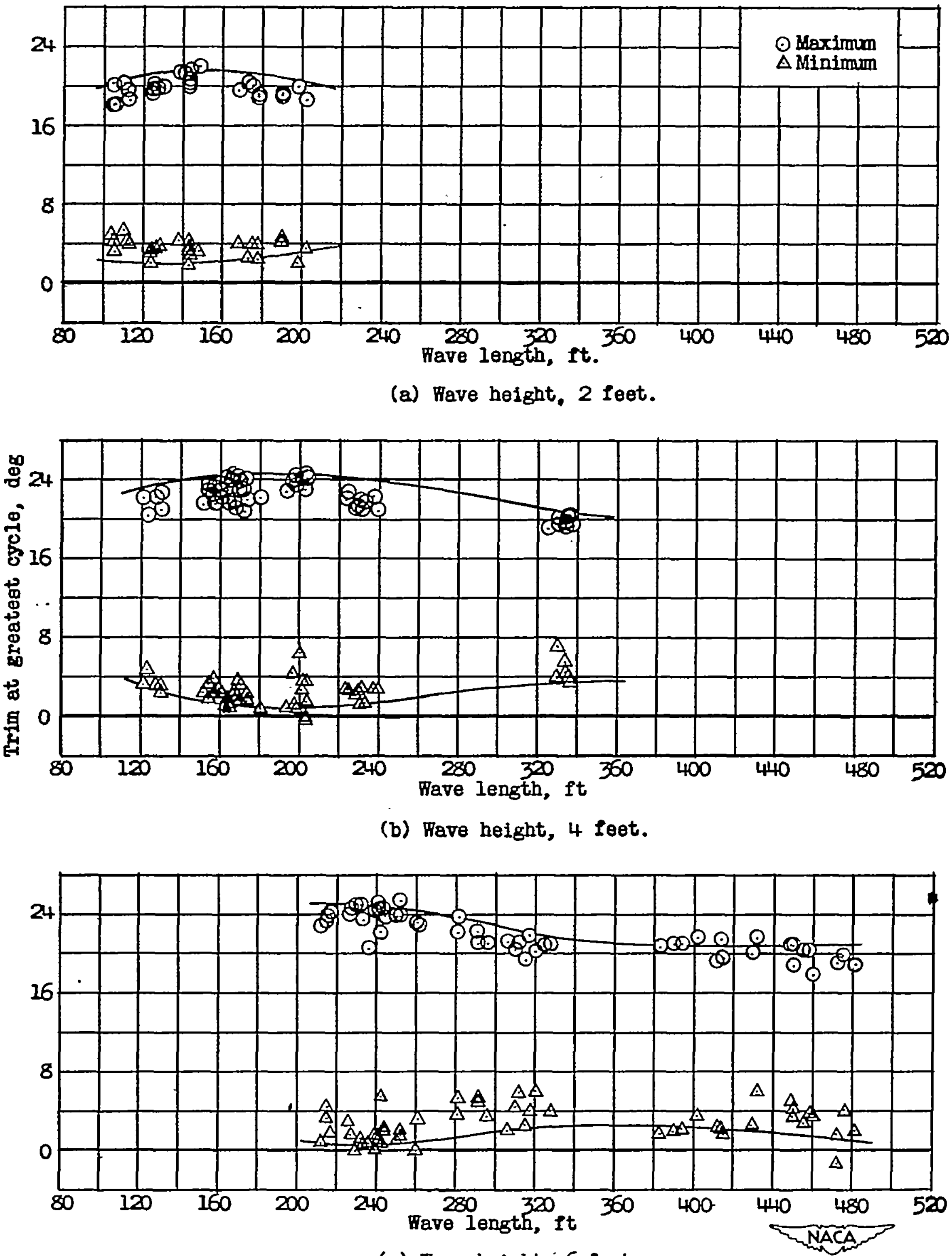
Figure 13.- Variation of maximum angular acceleration with wave length. Length-beam ratio, 15.



(a) Acceleration at initial contact.

(b) Maximum acceleration.

Figure 14.- Effect of length-beam ratio on angular accelerations.



(a) Wave height, 2 feet.

(b) Wave height, 4 feet.

(c) Wave height, 6 feet.

Figure 15.- Variation of maximum and minimum trim with wave length. Length-beam ratio, 6.

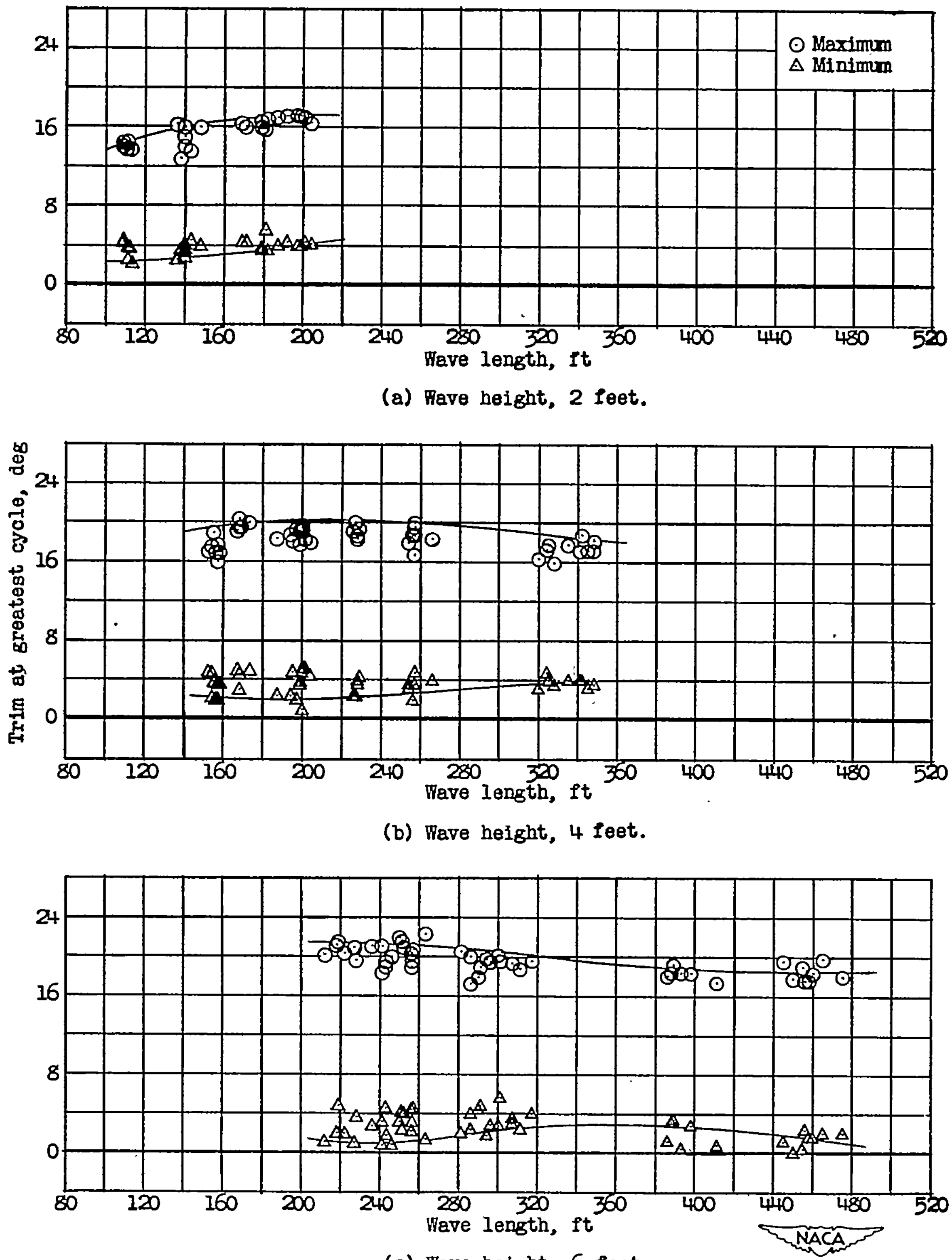


Figure 16.- Variation of maximum and minimum trim with wave length. Length-beam ratio, 15.

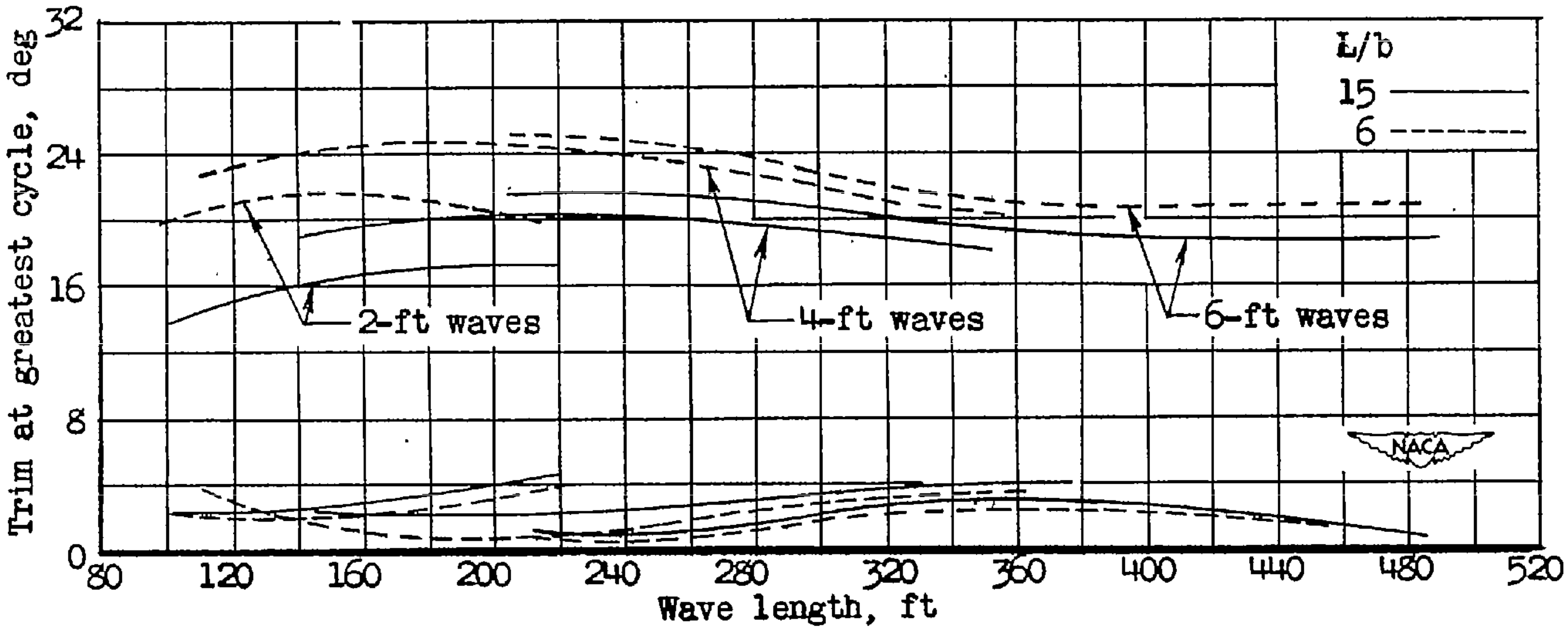
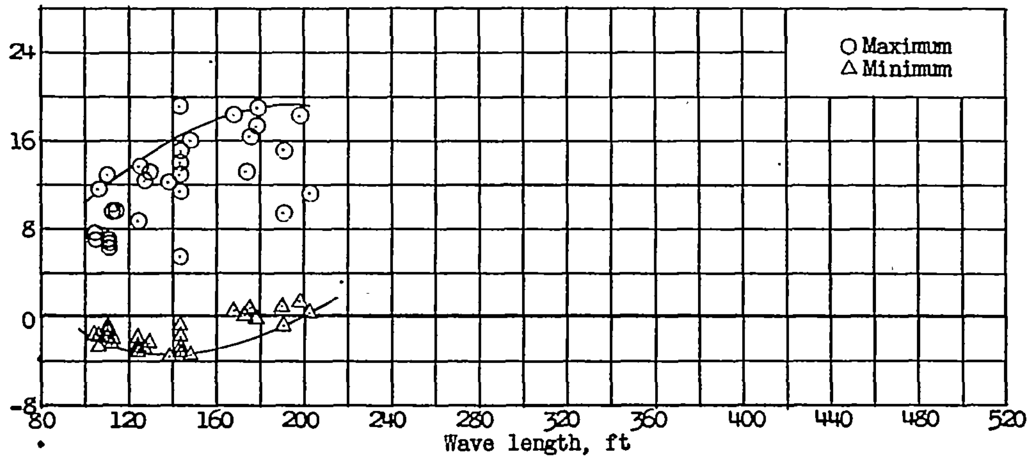
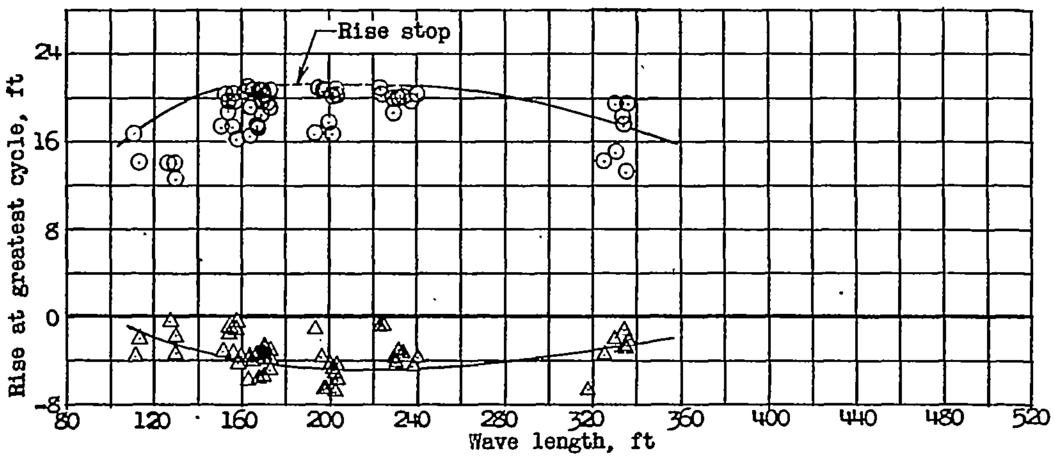


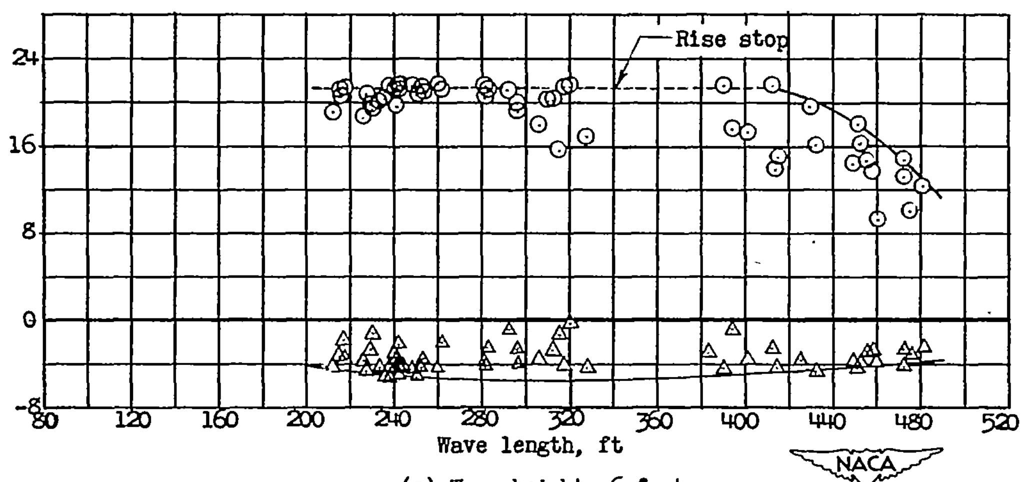
Figure 17.- Effect of length-beam ratio on maximum and minimum trim.



(a) Wave height, 2 feet.

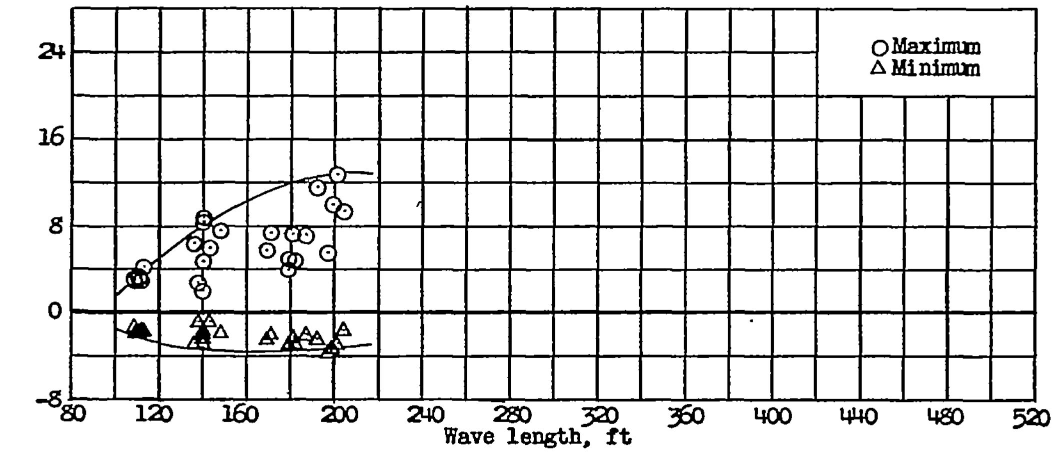


(b) Wave height, 4 feet.

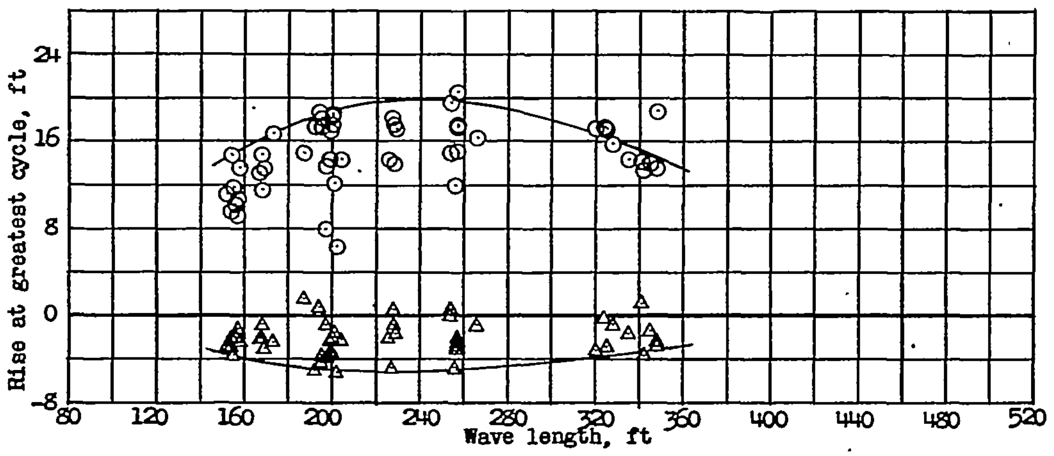


(c) Wave height, 6 feet.

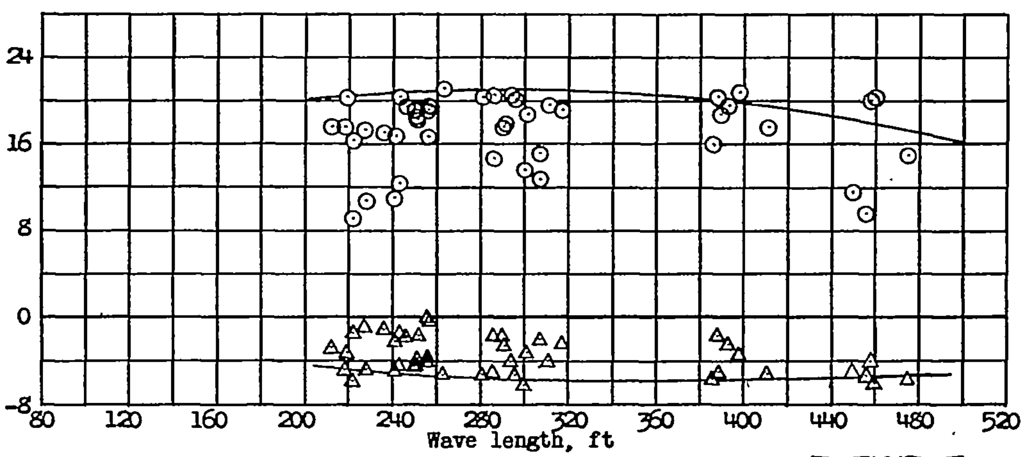
Figure 18.- Variation of maximum and minimum rise with wave length. Length-beam ratio, 6.



(a) Wave height, 2 feet.



(b) Wave height, 4 feet.



(c) Wave height, 6 feet.

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Figure 19.- Variation of maximum and minimum rise with wave length. Length-beam ratio, 15.

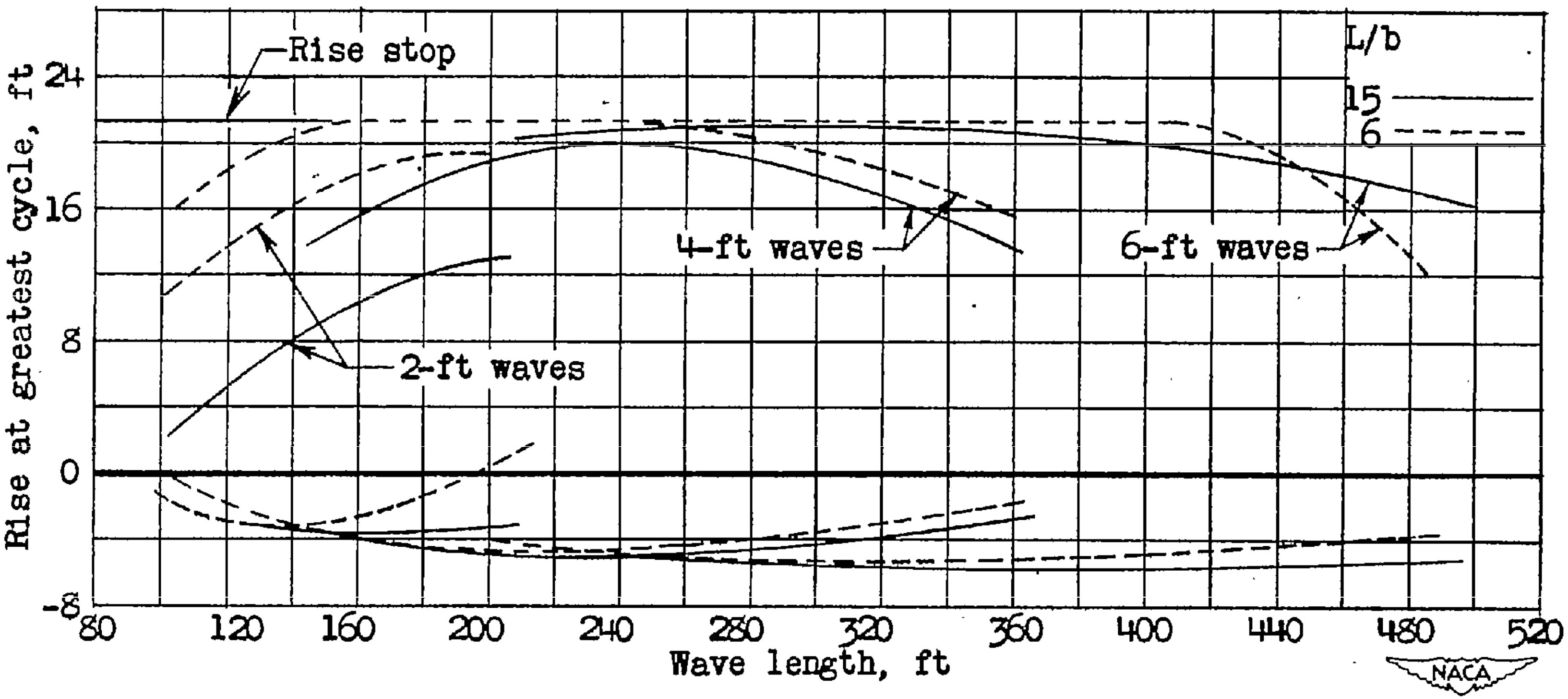
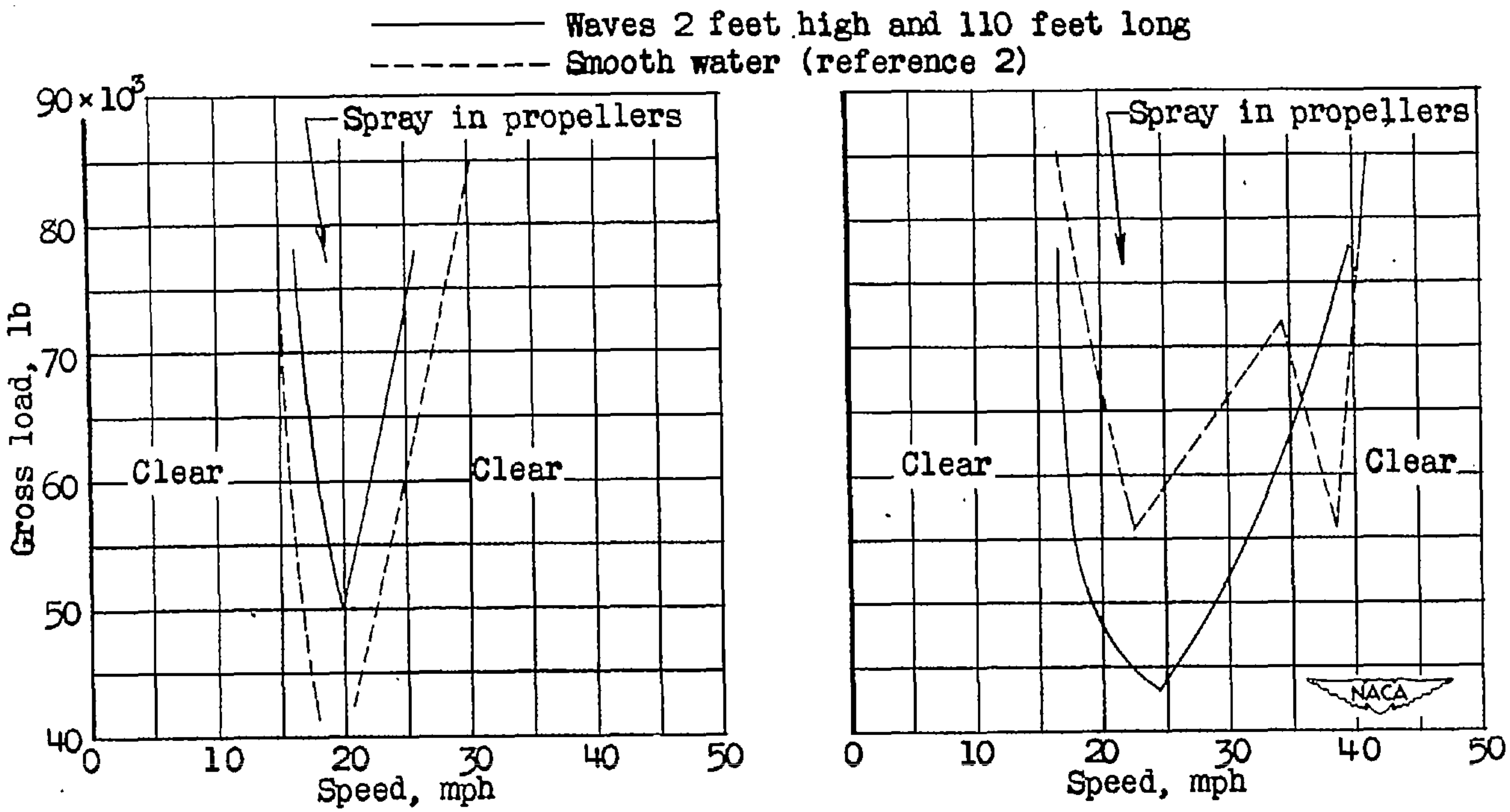
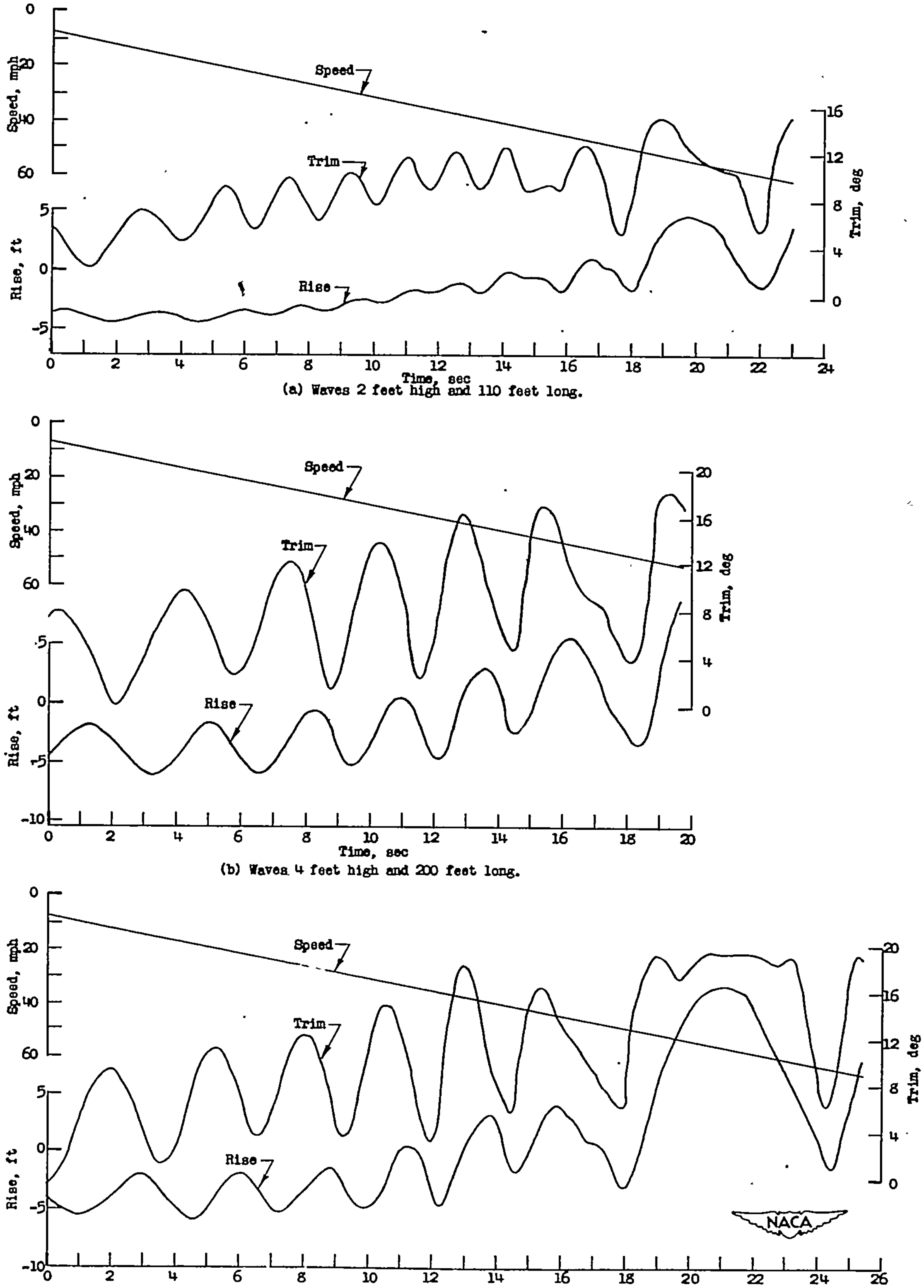


Figure 20.- Effect of length-beam ratio on maximum and minimum rise.



(a) $\frac{L}{b} = 6.$ (b) $\frac{L}{b} = 15.$

Figure 21.- Effect of waves on spray in propellers.

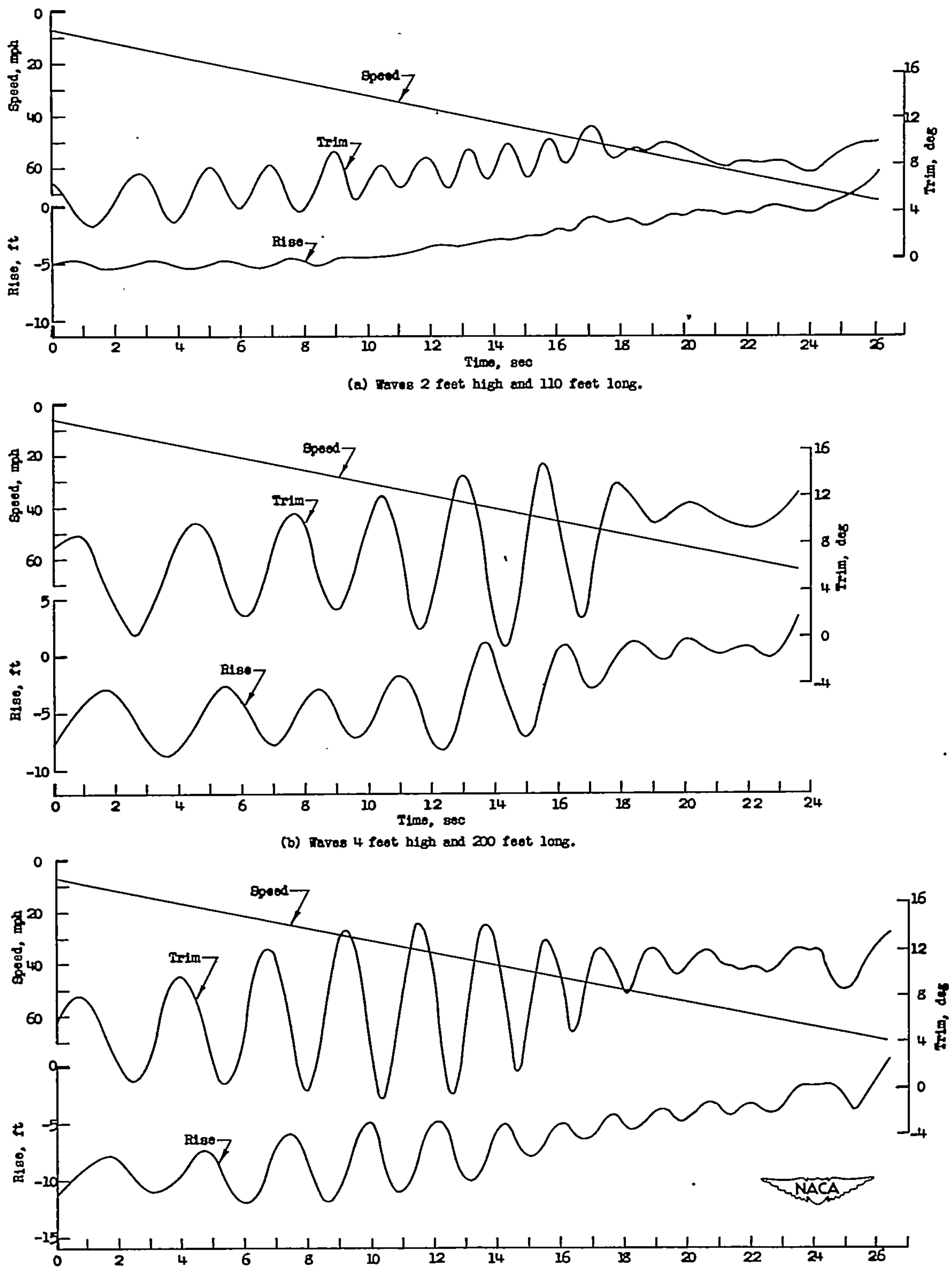


(a) Waves 2 feet high and 110 feet long.

(b) Waves 4 feet high and 200 feet long.

(c) Waves 4 feet high and 150 feet long.

Figure 22.- Tracings of typical records made during take-offs in waves. Length-beam ratio, 6.



(a) Waves 2 feet high and 110 feet long.

(b) Waves 4 feet high and 200 feet long.

(c) Waves 4 feet high and 150 feet long.

Figure 23.- Tracings of typical records made during take-offs in waves. Length-beam ratio, 15.